The 1989 Change in the Definition of Capacity: A Plant-Level Perspective

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Abstract: The Survey of Plant Capacity (SPC) is the primary source of data used to construct the Federal Reserve's manufacturing utilization rates. A major restructuring of the SPC in 1989 presents a potential obstacle to constructing measures of utilization that are consistent over time. The object of this study is to take advantage of plant-level data that is available at the Census Bureau's Office of the Chief Economist to thoroughly reexamine the link between the historical and current measures of capacity. The preponderance of evidence in this study suggests that "preferred" utilization is consistent with "full" utilization and, therefore, supports the underlying Federal Reserve methodology for estimating capacity utilization.

JEL codes: E22, L60

1 Introduction

The Federal Reserve publishes measures of output, capacity and capacity utilization for the industrial sector, measures that many consider to be useful indicators of inflationary pressure in the economy.[1] The Survey of Plant Capacity (SPC) is the primary source of data used to construct the Federal Reserve's manufacturing utilization rates. Given that an important goal in the construction of utilization is to produce statistics that are consistent over time, a major restructuring of the SPC in 1989 presents a potential obstacle to constructing time-consistent measures of utilization.

The 1989 comprehensive revision to the SPC included noteworthy changes to the definition of capacity in the questionnaire. Prior to 1989, the SPC requested two measures of plant capacity, preferred operations and practical capacity. After the survey revision, the SPC requested two new measures, full production and national emergency production.

The full production measure is currently the best survey measure of capacity available as national emergency capacity captures output at extreme wartime conditions. To generate utilization series that are consistent over time, one must determine the link between full production and the historical measures of capacity. A cursory examination of the definitions might suggest that practical capacity and full production would align quite closely. An examination of the data at the industry level, however, suggests that the preferred measure, rather than practical capacity, is more in line with full production. As a result, the Federal Reserve currently assumes a one-to-one link between the preferred and full measures to produce their capacity estimates.

The object of this study is to take advantage of plant-level data that is available at the Census Bureau's Office of the Chief Economist to thoroughly reexamine the link between the historical and current measures of capacity. As a background, Section 2 outlines the theoretical literature regarding capacity and then Section 3 reviews the SPC definitions of capacity prior to 1989. The restructuring of the SPC is described in Section 4. In addition,

[1]See Corrado and Mattey [1997] for an overview of the construction and usefulness of the Federal Reserve's capacity utilization rates.

the section discusses the implications of the survey change and presents some summary statistics. Section 5 discusses the methodology used to estimate capacity at the plant level. The empirical results used to generate estimates of the various measures of capacity are shown in Section 6. The next step, described in Section 7, is to aggregate the data into utilization rates at the industry level and then test the relationships between the old and new measures of capacity. In both simple summary statistics and detailed regression analysis, I find no evidence to suggest that practical capacity is better aligned with full production.

Generally, the results point to a one-to-one mapping between full utilization and preferred utilization. In order to provide a robustness check, I provide further evidence from an alternate estimation procedure, as explained in Section 8. The preponderance of evidence supports the assumption that preferred utilization is consistent with full utilization, and therefore suggests that the linking assumption underlying Federal Reserve methodology appears sound.

2 The Theoretical Definitions of Capacity

The concept of capacity appears to be quite straightforward at first glance. Defining and measuring the capacity level of output, however, can have practical difficulties as well as theoretical pitfalls. Winston [1977, p.418] provides an accepted form of the definition of capacity at the macro level:

> Capacity is the maximum sustainable level of output (per year) that can be got when an economy's available resources are fully and efficiently employed, given tastes and technology.

Translating the definition of capacity at the aggregate level into a clear concept of capacity at the establishment level is a complex issue considering that alternative measures of the capacity level of output at the plant level are possible. Typically, plant-level capacity refers to the output that a plant with a given stock of capital *can* produce in a given year. As noted in Klein and Long [1973], the amount that a plant *can* produce depends on a number of specific assumptions. The multiple ways of defining capacity at the establishment level highlight the substantial ambiguity in the capacity concept. For example, a plant can produce a certain quantity if it operates continuously throughout the year with no constraints on the supply of labor or materials, but this capacity amount likely differs from the quantity a plant can produce if it operates only for a 40-hour workweek because of labor constraints. Thus, the assumptions about the available supply of labor and materials affect our calculation of plant-level capacity.

In general terms, two distinct definitions of plant-level capacity output have been prominent in the literature, as discussed in Klein [1960] as well as McGuckin and Zadrozny [1988]. The first definition focuses on an engineering concept of capacity—the maximal output a plant with a fixed capital stock can produce without cost considerations. This level of engineering capacity is defined to occur when the short-run marginal cost curve becomes infinite. Equivalently, engineering capacity, represented by $\bar{q}$ in Figure 1, is the point where some input, such as capital, is exhausted and the marginal product of all other inputs is zero.[2]

This measure of capacity reflects extreme conditions such as wartime, and not more realistic peacetime conditions. Aggregating plant-level capacity using the engineering concept is problematic because such aggregation would not account for the economy-wide limitations in the supply of inputs. Such all-out production without regard for input supply generally cannot happen simultaneously for the majority of plants. For example, there may not exist adequate labor to fully employ every plant in a given industry simultaneously, yet an engineering measure would assume full employment at every plant. If the measures of capacity output at the plant level are to add up to a realistic amount of capacity output at the national level, input availability must be considered because, ultimately, the market imposes costs which likely contain production within realistic bounds below the engineering level of capacity.

[2]See McGuckin and Zadrozny [1988] for a further discussion of the capacity definitions shown in the diagram.

In response to the difficulties with the engineering measure of capacity, Klein [1960] and others have promoted an economic concept of capacity which incorporates cost considerations. As noted in Berndt and Morrison [1981], the economic capacity concept dates back to Cassels' paper in 1937. Unlike the engineering definition, the economic definition takes into account both labor and material costs. The advantage of the economic concept of potential output is that it should represent a level of output that is feasible for both the plant and the economy as a whole. Economic capacity is defined to be the level of output that occurs at the minimum of the average cost curve, shown as $\hat{q}$ in Figure 1.

Forrest [1979, p.28] describes an alternative definition of economic capacity at the point where marginal revenue equals marginal cost. The cost-minimizing and profit-maximizing definitions of economic capacity are equivalent in perfectly competitive industries in the long run, assuming homogeneous technologies. In other cases, the two definitions may signify different levels of output. As noted by de Leeuw [1979, p.28], the level of maximum profits may fluctuate cyclically as a result of movements in price and possibly cost. The minimum average cost definition, however, should be less cyclical reflecting only the fluctuation in cost.

The economic definition of capacity appears to have conceptual advantages over the engineering definition. Nonetheless, in practice, the economic definition of capacity presents the difficult problem of estimating cost functions. Christiano [1981, p.169-70] argues that capacity defined in a least-average cost sense may require more information than a business actually has. He also suggests that a request for a very precise definition of capacity would stymie the survey respondents.

3 The Survey of Plant Capacity

Measures of capacity were published during the sixties and seventies by the Bureau of Economic Analysis (BEA), the Wharton School of Finance, the McGraw-Hill Publishing Company, and the Bureau of the Census. Of these, only the Bureau of the Census measure remains. Unfortunately, no survey of capacity appears immune from problems; constructing an actual consistent time-series of capacity has proven to be a formidable task because of both practical and conceptual difficulties. Berndt and Morrison [1981, p 48] state that the link between actual measures of capacity and the theoretical definitions described above is quite weak, making it difficult to interpret the relative movements in these series. Forrest [1979, p.72] adds that measuring capacity is straightforward in only a handful of industries, such as paper.

The Federal Reserve index of capacity is currently based on the Census Bureau's Survey of Plant Capacity (SPC) and available trade association data. The SPC is an annual survey of fourth-quarter operations from a subset of the plants in the Annual Survey of Manufacturers (ASM). Before 1989, the SPC contains information about the plant's "actual output", "practical capacity" and "preferred level of operations". The precise wording of the definitions of capacity is shown in Table 1. In addition, respondents are given some guidance in calculating capacity figures with a list of assumptions, shown in Table 2. The survey remains basically intact with only minor changes over the 1974-88 period.

3.1 Practical Capacity

The definition of practical capacity, which corresponds most closely to the concept of engineering capacity, has a couple of advantages despite the aggregation problems mentioned in the previous section. First, studies (see Schnader [1984, p.81] and Christiano [1981, p. 168]) have suggested that many respondents tend to use some version of practical capacity whenever they respond to a survey. Second, for continuous-processing industries such as paper, steel, aluminum and cement, the engineering concept is a natural way to think about capacity, and in these industries, it should coincide with most other concepts (Christiano [1981, p.145]).

The Census Bureau does acknowledge that its survey is not exempt from the problems faced by all such surveys.[3] They confess in various reports that

[3]See Appendix B of the U.S Department of Commerce reports (1974-88) for more details.

> although survey respondents were provided detailed instructions for estimating practical capacity, it is extremely difficult to translate the concept of plant capacity into a working definition which is applicable to all industries and situations.

Based on follow-up visits and phone calls, the Census Bureau identified some of the more significant problems with practical capacity. First, respondents tend to use a variety of methods to compute their estimate of capacity. They may estimate capacity using the maximum number of work hours, a past peak performance, or a number of other measures. Second, the respondents, particularly at plants that produce a variety of products, sometimes have difficulty determining realistic work patterns and normal product mixes. Third, it is apparent that not all respondents provided realistic estimates. For example, some establishments defined potential output based on continuous operation, despite admitting that they had actually operated only one shift and could not have realistically increased their workweek by a significant amount.

As discussed in McGuckin and Zadrozny [1988], the practical capacity measure was designed to conform with the engineering concept of capacity (point $\bar{q}$ in Figure 1). Forrest [1979, p.67] points out, however, that the SPC definition of practical capacity is really a combination of both the engineering and economic concepts of capacity. Typical of most surveys of capacity, the SPC uses a definition that is somewhere between the two extreme interpretations of economic and engineering capacity. The economic considerations come in two noteworthy places. First, in the definition itself, shown in Table 1, which directs the respondent to compute capacity considering a "realistic work schedule". Second, Assumption 3a, shown in Table 2, also introduces economic considerations by directing respondents to use a reasonable workweek. Forrest [1979], Winston [1977], and Christiano [1981] all point out that assumptions like Assumption 3a are really economic considerations given that economic forces such as costs influence standard work patterns and, thus, influence the realistic workweek.

3.2 Preferred Level of Operations

While practical capacity is intended to correspond, at least somewhat, to the engineering concept of capacity, the preferred-operations measure was designed as more of an economic concept. Even so, the SPC does not specifically ask for the more commonly accepted theoretical definition of economic capacity—the cost minimizing level of output. As shown in Table 1, preferred operations is defined to be the level of output "you would prefer not to exceed". Then the instruction form states that the preferred level also implies that there exists a profit-maximizing level of output. The form then reminds the respondent that this level of output may not exceed practical capacity.

The imprecise wording of the SPC survey form for the definition of preferred operations appears to generate a great deal of confusion. McGuckin and Zadrozny [1988] note that it is somewhat unclear to respondents how preferred operations should differ from practical capacity and from actual output. McGuckin and Zadrozny make the straightforward point that, with a short-run view, it seems that actual production and the profit-maximizing level of output should be the same.

Table 3 presents a percentage breakdown of plants into four categories, depending on whether respondents set preferred operations equal to actual output and whether respondents set preferred operations equal to practical capacity. If taken literally, the survey results shown in Table 3 indicate that most respondents did not produce at their profit-maximizing level. Adding together the results in the last two columns shows that fewer than 20% of respondents report their preferred level of operations equals actual output. McGuckin and Zadrozny interpret these survey results as evidence that respondents are identifying capacity output as the expected production in long-run, which implies that plant managers would identify point q^* in Figure 1 as the preferred level of output.

Long-run expectations may play an important role in the respondent's answers but there are, however, other possible interpretations. Uncertainty about input supply or output demand may also explain the difference between actual production and preferred operations. It is possible that some respondents report their preferred level of operations as the expected, rather than actual, profit-maximizing point. In Figure 2, suppose the producer expects favorable conditions for demand and costs, shown as MR' and MC'. As a result of profit-maximizing decision-making, the plant expects and reports preferred operations to be based on point C. Actual production would then be the profit-maximizing point after experiencing any unanticipated negative shocks to demand and input supply. Thus, depending on the outcomes, marginal revenue could be MR or MR' and marginal cost could be MC or MC'. Depending on the outcome, the producer could base the output decision as points A, B, C, or D.

Survey results provide some support for the uncertainty hypothesis. The survey questionnaire includes several check boxes inquiring into the principal reasons why a plant fell short of its preferred level of operations. The percentage breakdown of the primary reasons are reported in Table 4. The results of Table 4 suggest that some respondents were surprised either by weak demand or by production troubles, and accordingly cut back production. The numbers clearly show that the category for insufficient orders is, by far, the most prevalent reason that a plant produced less than its preferred level. Moreover, insufficient orders is the most frequent answer in any category, including all manufacturing and grouping by technical class.

Stepping back, the results in Table 3 present another puzzle; the majority of respondents report preferred operations as equivalent to practical capacity. If producers make investment and other long-term decisions based on expectations of favorable conditions in order to avoid missing potential profits, they may target this profitable output near the practical capacity level. Another possibility is that the definitions are unclear enough that respondents just use their own concept of capacity for both questions. Several studies, such as Schnader [1984, p.81] and Christiano [1981, p.168], suggest that whenever respondents are unsure about a survey definition of capacity, the respondent tends to write down some practical-like number. Whatever the reason, half or more of the respondents have reported that their preferred operations are equivalent to their practical capacity.

Given the distinct differences in capacity definitions, one would not have expected such a high frequency of equivalent estimates except in the continuous-processing industries. As noted in Christiano [1981, p.145], the engineering concept of capacity is the natural one and all other concept may coincide for continuous-processing industries. Figure 3 demonstrates what may happen in these capital-intensive industries where plants run almost continuously. The marginal cost curve may be flat or decreasing up to a point where nothing can be produced without additional capital. At this point, marginal cost goes to infinity.

Returning to Table 3, it, however, can be seen that the majority of respondents in any technical class report the two concepts of capacity as equivalent, suggesting that these results are broad-based and not just driven by the continuous-processing industries.

4 The Revised Survey of Plant Capacity

The general perception that the two separate survey questions on capacity, preferred and practical, were unclear and not working as intended prompted a revamping of the capacity definitions in the new version of the survey, which was implemented in the 1989-90 survey. The SPC questionnaire was also drastically reconstructed as funding cuts and concerns about respondent burden prompted the Census Bureau to streamline the survey. The Bureau of the Census restructured the definitions of capacity level, attempting to improve the consistency across industries and to ease some of the reporting burden. Simultaneously, the survey switched to being a biennial survey rather than an annual survey.

Full production, the new survey definition, refers to the "maximum level of production that this establishment could reasonable expect to attain under normal operating conditions." The complete definition and accompanying assumptions are shown in Tables 1 and 2. The definition of full production is quite similar in wording to that of practical capacity with only a few small differences between the two. In the definition itself, the question for full production refers to "normal operating conditions" while the question for practical capacity refers to a "realistic employee work schedule" (see Table 1).

The corresponding list of assumptions are somewhat different. After 1988, when considering full production, respondents are asked to follow the directions in Assumption 3b in Table 2. Assumption 3b is much more restrictive than Assumption 3a, which was used in the earlier survey. Assumption 3b was eventually considered to be too restrictive and was changed back to Assumption 3a in the 1995-96 survey.[4] Another potentially important change in the survey was the removal of Assumption 7. This assumption originally eliminated the constraint on capacity by limited available inputs. Without this assumption, respondents may consider these factors to be limiting factors.

The survey also inquires about national emergency production, a level of production that could be sustained for at least one year under national emergency conditions–a more pure definition of engineering capacity.

4.1 The Link Between the Two Surveys

Despite subtle differences in the definition of practical capacity and full production, the similarities in the basic definitions might suggest that these two measures should be tightly linked in practice. However, the changes in the survey's set of assumptions, shown in Table 2, which were intended to provide guidance to respondents in estimating capacity, may affect the plant manager's calculation of capacity. In particular, respondents were asked to consider Assumption 3b rather than Assumption 3a when computing full production. This assumption encourages additional economic considerations when computing plant capacity.

For many respondents with realistic views regarding their feasible work period, constraining the workweek to be within the range experienced by the plant over the previous five years may not be a binding constraint in the early nineties, given that 1988 was a peak in Federal Reserve estimates of manufacturing utilization. Note that Assumption 3b was apparently put in place by the Census Bureau in an attempt to curb unrealistic estimates of feasible workweeks. For those respondents with unrealistic workweek expectations, the implementation of Assumption 3b may reduce their capacity estimate and boost the corresponding

[4] The empirical analysis was restricted to the pre-1995 period in order to minimize survey changes within the sample.

utilization rate. Overall, the introduction of Assumption 3b may have subdued capacity estimates.

The revamped SPC includes other changes to the set of assumptions. Assumption 1, used for both practical and full capacity, guides respondents to ignore cost considerations, making the capacity estimate more of an engineering concept. The usefulness of Assumption 1 may be nullified over the 1989-94 period. Plants make decisions about shifts and plant operating hours based on cost considerations. If respondents are asked to take into account the maximum work period experienced over the previous five years, which was determined by cost considerations, it may be difficult for the respondent to simultaneously ignore cost considerations such as overtime. Another change, the elimination of Assumption 7 regarding availability of inputs, adds another economic consideration to the full production measure. Given that Assumption 1 remains in place, the implications of removing Assumption 7 are not obvious.

Other changes to the survey have uncertain effects. For the period 1989-94, the survey is collected every two years, rather than every year. In addition, the survey design was changed so that respondents report capacity as a percentage of actual output. Earlier surveys requested capacity estimates in dollar amounts. The survey also added a new concept of capacity, the national emergency measure which specifies that respondents estimate plant capacity under wartime conditions. It is possible that the national emergency question provides some perspective on peacetime conditions.

In principle, the changes just listed should not affect survey results. Nonetheless, a large body of literature, including Schwarz and Sudman [1996], Sudman, Bradburn and Schwarz [1996] and references therein, have been devoted to study of the sensitivity of responses to the way in which questions are asked. This literature suggests that even small changes in questionnaire wording can produce dramatically different results. In light of the survey literature, it is possible that seemingly irrelevant differences may influence capacity estimates.

Taken together, the changes made in 1989 to the SPC have an unclear effect on respondents. Ultimately, the relationship between full, practical and preferred utilization rates is an empirical question.

The plant-level data allows for an in-depth examination of the capacity responses. As a preliminary look, Table 5 reports some summary statistics for the 1235 reporters that had completed surveys in both the 1988 survey and the 1990 biennial survey. The table first presents unweighted means for a simple comparison. The statistics shown in the top portion of the table do not present any strong evidence about the links between the definitions. Full production utilization in 1989, at about 83 percent, appears equidistant from the two capacity measures in 1988. To glean more information from this data, I recompute the measures as ratios, full relative to preferred utilization and full relative to practical utilization. This computation measures the average relationship between the utilization rates within a given plant, rather than comparing overall sample means. The bottom portion of Table 5 presents the average of the ratios of the two utilization rates. On average, a plant's full utilization in 1989 is 1.01 times its preferred utilization rate in 1988 while the ratio of full to practical utilization is 1.08. The results presented here appear consistent with the assumption that full utilization aligns more closely with preferred. Yet, without knowing what the innovation in utilization between 1988 and 1989 was, these comparisons provide little evidence regarding the relationship between the different capacity definitions.

Figure 4 presents aggregate measures of the three SPC utilization rates over time that suggest the full production in 1989 lines up quite closely with preferred utilization in 1988. These kind of comparisons, however, have unclear worth as we are comparing figures in two separate time periods rather than within the same year. It is possible that, between the fourth quarter of 1988 and the fourth quarter of 1989, utilization rates shifted sharply upwards; in this scenario, the chart would imply that practical utilization may actually link up with full utilization.

The upward-shift explanation appears unlikely as there is no real evidence of an upward shift of such a large magnitude in this period. I have constructed estimates of preferred and practical utilization for 1989 based on regression results.[5]. The estimates are then aggregated

[5]The results are described in Section 6 and presented in Tables 11 and 14

to the manufacturing level. The preferred and practical estimates allow for a more direct comparison within a given year.[6] The estimated rates in 1989 suggest that there was an upward innovation in preferred and practical utilization rates in 1989, but not so sharp a movement that practical utilization aligns with full utilization.

With this additional check, it still appears that preferred utilization is the best measure to link with full utilization. In general, users of the data would prefer to know the behavior of full utilization prior to 1989. As an answer to this question, the empirical analysis presented in the next sections provides some estimates of full utilization.

5 The Empirical Specification

The lack of an overlap in the time periods of the new and old capacity definitions presents an obstacle in examining their statistical relationship. I use the plant-level information to generate estimates of full production for the 1974-88 period, making a more direct comparison of the capacity measures possible. This section describes the methodology used to generate an estimate of full production. The first part of the section focuses on the data and the variable construction. Then, the specifications used to generate the capacity estimates are discussed.

5.1 The Data

The SPC is an annual survey that contains information on output, capacity, plant operating hours, and reasons for changes to capacity. The survey covers about 8000 plants per year. The aggregate data based on the survey are published by the Census Bureau as part of its Current Industrial Reports program.

[6] In this figure, the measures are constructed by aggregating the plant-level data. The plant's observation was included in the aggregation only if all utilization rates, including the estimated preferred and practical measures, were available. Specifically, if one could not construct an estimate of practical capacity based on the regression results for a given plant, then that plant was dropped from the sample. Thus, all measures are sample consistent.

To produce estimates of full production, the plant-level observations from the SPC are linked with the Annual Survey of Manufactures (ASM) data. Until 1995, the sample used in the SPC was a sub-sample of the ASM, which is not a random sample. Both surveys oversample large plants. Sampling weights are designed such that weighted averages would be representative of the population.[7]

The plant-level data contain both unedited observations for some respondents and imputed numbers for non-respondents and require a non-trivial amount of screening. In preparing the data for analysis, I follow the work of Mattey and Strongin [1994]. For an observation to be included in the usable sample, it must have non-missing values for all variables regarding capacity, production, workweek, and production workers. Since the Census Bureau only imputes values for production and capacity, this process of elimination should remove all imputed observations.

The Census reports publish only the utilization rates, and so, only those variables in the dataset have been carefully screened for recording errors. To check the less-reviewed variables, I have screened the data for any obvious typographical or processing errors. Following Mattey and Strongin [1994], I drop any observation that violates the following constraints: shifts-per-day variables must range from 1 to 3; days-per-week variables must range from 4 to 7; hours-per-day variables must range for 6 to 24; weeks-per-quarter variables must range from 6 to 15; output and employment variables must be greater than zero; production-worker hours must exceed employment; and the four-digit SIC industry must be in manufacturing. I then match the cleaned version of the SPC to the ASM. With the resultant dataset in hand, I construct estimates of capacity.

5.2 Methodologies for Estimating Capacity

Several of the standard approaches for estimating capacity are not feasible given data limitations. For example, Mattey and Strongin [1994] estimate capacity growth using two measures, the change in labor intensity at capacity and the change in the work period at

[7]The microdata has been made available at the Census Bureau's Office of the Chief Economist.

capacity, that are unavailable between 1988 and 1997. Thus, the exact methodology used in Mattey and Strongin [1994] to analyze practical capacity prior to 1989 is not possible here. As discussed below, I do include some of the variables used in Mattey and Strongin in my analysis of full production. Specifically, I include a set of dummy variables that indicate plants' primary reasons for changing capacity over the past year, variables that are available in every survey year.

Many aggregate studies of capacity, which include Mohr and Morin [1998], use capital stock information to estimate capacity. This estimation approach is also not possible in this study as adequate information on the capital stocks at the plant level is not consistently available. The annual investment data are problematic but available. In the end, the investment data did not prove useful in estimating capacity *levels*. Investment data may be useful in estimating capacity *growth* but that is not the objective in this study. If we were to look at changes in capacity, then we would be constrained to estimating full production levels within one year of having actual data, i.e. just 1988, rather computing estimates for the whole 1974-88 period.

One standard approach to estimating capacity proved more feasible, using peaks of production. Several key studies, including Klein [1960], Christiano [1981], and Schnader [1984], discuss the usefulness of peaks of production to approximate capacity. Schnader notes that observed peaks in performance are a reasonable measure of attainable output. Despite some criticisms about the peak-production approach, it is well accepted in practice, particularly at the aggregate level. For example, the peak-production methodology was employed to compute the Wharton index of capacity (Christiano [1981, p.150]). Unlike the other methodologies, the peak-production approach is manageable in this study, as we have annual production data for a panel of establishments.

5.3 Empirical Specification

This study uses a peak-production approach at the micro level to estimate capacity. Specifically, I take advantage of the panel aspect of the data, and run a fixed effects model for full production with the establishments' production peaks as one of my primary explanatory variables. Here, capacity for plant i in year t is a function of its maximal production, denoted as $MAX\ P$, and other explanatory variables, denoted as Z,

$$Capacity_i = F(MAX\ P_{i,t-2}, Z_i) \tag{1}$$

Below, I describe the construction of the variables used in the panel regressions. The micro-level regressions that are used to estimate full production employ a set of explanatory variables that are briefly described in Table 6.

Instead of using one measure of maximum production, I have chosen three measures to capture the recent production behavior of the plant. Making use of the data back to 1974, I compute the maximum production that a plant has experienced. All of the available data provides a reasonable estimate of the maximal plant output. For regression purposes, I choose, as a key explanatory variable, the maximum production that a plant in year t has experienced by the year $t-2$, represented by $MAX\ P_{t-2}$. Then, to determine whether the plant has expanded recently, I also include–$P_{t-1} - MAX\ P_{t-2}$–the difference between production in year $t-1$ and $MAX\ P_{t-2}$. If the maximum output experienced by the establishment has recently increased, then $P_{t-1} - MAX\ P_{t-2}$ is positive. Moreover, a positive value for $P_{t-1} - MAX\ P_{t-2}$ may affect capacity differently than a negative value which suggests no expansionary pressure on the plant's facilities. To account for this potential asymmetry, I include $(P_{t-1} - MAX\ P_{t-2}) * I_+$. The variable $(P_{t-1} - MAX\ P_{t-2}) * I_+$ is simply the variable $P_{t-1} - MAX\ P_{t-2}$ interacted with a dummy equal to one whenever $P_{t-1} - MAX\ P_{t-2}$ is positive.

Following Mattey and Strongin [1994], I also consider a set of qualitative variables that indicate the major reasons driving a plant's change in capacity from the previous year, denoted as the ΔCAP variables. There are eight such dummy variables, determined by a set of check boxes on the SPC form. As shown in Table 6, the first four variables signify possible changes in capacity spurred by changes in the capital stock through an expenditure or a retirement to either buildings or machinery. The survey also asks about changes in the method of operation, changes in product mix and changes to inputs. In addition, some respondents simply checked the box for "other". If the respondent did not report any reason, then each of the eight variables will equal zero.

In an effort to capture plant size, both relative to other plants and relative to other time periods, I include several measures of the plant's labor force, available from the ASM. The variable TE represents the total employment of the plant and $NPWE$ represents the number of total non-production worker at the plant. I also included the percent change of both variables to capture recent movements in plant size. Each of the labor variables is useful in at least one of the regressions discussed below. In a parallel approach, I attempted to employ the actual workweek variables, but these did not significantly contribute to the explanatory power of the regression.

Information on recent business conditions also help explain capacity at the plant level. I include information on shipments, both at the plant and industry level. The total value of shipments for the year are available at the plant level in the ASM. In the regression, I have a lagged value of shipments, $PLTSHIP_{t-1}$, and the annual percent change in shipments, $\%PLTSHIP$. It is possible the plants adjust capacity differently depending on whether shipments have been increasing or decreasing. To control for any potential asymmetries, the specification includes $(\%PLTSHIP) * I_+$. To represent the state of the whole industry at the four-digit SIC level, I also include the annual growth in industry shipments, $\%INDSHIP$, based on data from BEA. All variables measured in dollars have been deflated by shipment deflator, also computed by BEA.[8]

A time trend and a squared time trend are also included in the regression equation to capture any general movements over time. In addition, a cost of capital measure, $COST\ of\ K$, is also in the specification. Corrado and Kortum [1995] describe the role of the rental price of capital in capacity. A description of the variable construction is available in the appendix of their memo. I match the relevant $COST\ of\ K$ at the three-digit SIC level to each

[8]Both variables from BEA were collected from the diskette produced by BEA on "Manufacturing Establishments Shipments".

establishment in the SPC.

My econometric analysis is split by technical class. The literature frequently mentions that capacity is a more straightforward concept for one technical class–the continuous processors. Continuous-processing plants tend to have large shut-down costs and operate continuously. In order to differentiate between the three standard technical classes, I run the specification separately for each class. I designate a plant into a category following the criteria set in Mattey and Strongin [1994] at the four-digit SIC level. To adjust output, the plant changes the rate of production.

I qualify an industry as a continuous processor if the average workweek in their four-digit industry exceeded 150 hours per week, which requires that plants operate more than 21 hours per day in a seven-day workweek.

The remaining industries are split into a Variable-Work Period category and an Other category based on the four-digit industry's coefficient of variation (CV) in the work period of capital.[9] Assembly-style plants tend to have a low shut-down costs and often vary their work period to adjust output. If the industry's mean CV was above the mean CV for all of manufacturing, then that industry was assigned to the assembly or Variable-Work Period category. The remaining industries fell into the Other category. Using an excerpt from the fourth table in Beaulieu and Mattey [1995], Table 7 illustrates a distribution of technical groupings within the two-digit industries.

6 Results of the Micro Analysis

Full production can be estimated using the explanatory variables described above. Table 8 presents the results of the three regressions used to estimate full production. The regression panel covers the years 1989 through 1994. Because there are thousands of plants, estimating fixed effects is quite onerous. To circumvent the logistical problems of the estimation, I employ an empirically-equivalent methodology, using a partitioned regression or

[9] For each plant, the CV was computed as the ratio of the standard deviation to the mean of the work period.

deviations-from-means approach, as discussed in Greene [1997]. Thus, the predicted values are estimates of the deviation in a plant's capacity level from its average. Fundamentally, we care about how well we estimate the capacity level, not its deviation. The R-square statistic can be misleading in these circumstances. With this in mind, the explanatory power of the regressions is not so weak.

Computing the actual estimate of the capacity level is straightforward; I add the mean level of capacity for plant i to the predicted deviation. Taking these estimates of full production, together with the actual measure of full production for 1989-1994, I recompute an R-squared statistic using the standard formula described in Greene [1997]. The results are shown in the last row of Table 8. The explanatory power of the regression now look quite good, once one incorporates the level adjustment.

The empirical results of Table 8 indicate that $MAX\ P_{t-2}$ and its related measures significantly help to explain full production. If the maximum level of production increased in the previous year by more than average, i.e. $(P_{t-1} - MAX\ P_{t-2}) * I_{+}$ is greater than zero, the results suggest that a plant's capacity is likely to be higher.

$MAX\ P_{t-2}$ is constructed so that maximum production can never decrease over time, t. Thus, if maximum production is less than its average over the time period, production must be increasing in the future. Capacity at a plant may be high when $MAX\ P_{t-2}$ is lower-than-average because the plant manager anticipating this future increase in production. The regression results do indicate that the production variables are useful in estimating full production.

The next set of explanatory variables, the labor force variables have mixed success. As might be expected, the labor force of the plant was particularly useful in explaining capacity for the plants in variable-work period industries. If growth in total employment is higher than average, then the plant's capacity is expected to be greater relative to its average. It, however, appears that more non-production workers do not necessarily have a positive effect on capacity.

The business conditions data also help explain variation in capacity, as shown by the coefficients, $\%PLTSHIP$. If last year's shipments were higher than average, the plant will likely boost capacity. After controlling for plant shipments, the variable measuring industry shipments has a marginal role. Both the squared time trend and the cost of capital variables have significant explanatory power as well.

Using the regression results, estimate of full production at the plant level can be readily computed. The predicted values of this estimation are then aggregated and used for a within-year comparison with the other definitions in capacity.

To fully take advantage of the data, I also performed the reverse experiment. By changing the regression's time period to 1976 to 1988, the specification can also be used to estimate both preferred and practical production. The same methodology and set of explanatory variables apply here. The only difference is that I ran six separate regressions instead of three. For each technical class grouping, I divided the observations into two categories, the responses where practical capacity equaled preferred operations and the responses that did not. This split accounts for the fact that there may be noteworthy differences between the two response categories. Though not discussed, the results of these regressions are presented in Tables 11 through 14.[10] The estimates of preferred and practical are then aggregated, following the procedure described below, and used to illustrate the innovation in utilization between 1988 and 1989 in Figure 4.

7 Aggregate Analysis of the Capacity Definitions

I follow the methodology used by Census to translate plant-level responses in the SPC into industry-level utilization rates to aggregate all of our establishment-level data into a four-digit SIC, j. With data for plant i on actual production, $Prod$, and capacity, Cap, utilization

[10] Tables 12 and 14 appear to be the same regression. The coefficients are slightly different because of the plant level fixed effects.

for industry j can be computed as

$$u_j = \frac{\sum_i w_i \cdot Prod_{ij}}{\sum_i w_i \cdot Cap_{ij}},$$

where w_i are weights provided by the Census Bureau.

Whenever actual capacity data is in hand, it is used in the above equation. Otherwise, I employ the regression-based estimates. For example, I use estimates of full production to calculate industry-level full utilization prior to 1989. Likewise, I calculate preferred or practical utilization in 1989 with the estimated values.

To aggregate further, I again follow Census methodology,

$$U_k = \frac{\sum_j VA_j}{\sum_j (VA_j/u_j)}.$$

where U_k is the utilization for the kth industry (K can be a two-digit SIC or total manufacturing) and VA_j represents ASM data on the value-added for a four-digit SIC industry j.

The primary goal of this study is to reexamine the full-preferred relationship to determine whether the assumed link between the two measures appears valid in light of the micro-level estimations. The aggregate utilization rates can be used to make comparisons between preferred, practical and full utilization as illustrated in Figures 5 through 25. An ocular regression of Figure 5 suggests that full utilization for total U.S. manufacturing better aligns with preferred utilization. In most cases, full utilization moves closer in line with preferred utilization. In addition, Figures 6 through 25 generally provides a picture of full utilization that is in line with, or above, the preferred utilization rates for the two-digit industries.

Only a few industries present a different picture. Industries 26 and 27, shown in Figures 12 and 13, are more difficult to interpret and do not clearly depict a tighter relationship between full and preferred utilization. However, making such a distinction in these two industries appears less relevant as the measures of preferred and practical utilization move together fairly tightly.

Two other industries, 29 and 31, also appear to deviate from the general trend. Industry 31, however, is a very small industry, and as can be seen in Figure 17, the data are even insufficient to generate an annual value in some years. Overall, it is difficult to interpret a relationship between the different utilization rates shown for Industry 31. In the case of industry 29, full utilization appears to move more strongly with practical capacity. It is also noteworthy, and shown in Table 7, that industry 29–the petroleum industry–is the most heavily concentrated with continuous-processing production. The literature has suggested that continuous processors have a standard view of capacity that is similar to the definition of practical capacity. Nonetheless, these results from industry 29 do not have strong implications for Federal Reserve methodology which relies primarily on detailed physical product data available from trade associations for estimating that industry's capacity.

After the more casual visual examination of the results, a more rigorous statistical approach is in order. To test statistically whether full utilization aligns with preferred utilization as previously assumed, I run a set of hypotheses tests. First, I run a set of regressions of practical utilization on preferred utilization. A separate regression is run for manufacturing and for each two-digit industry. The regressions include the annual data for 1976-88 and their results are not reported. I then compute residuals to be used in the next stage of regressions.

The regressions are corrected for serial correlation using Prais-Winsten methodology. Then, using data from 1976-88, I run full utilization on preferred utilization and the residuals from the practical utilization regressions. The residuals are used, rather than practical utilization itself, in order to determine whether the practical utilization contains information, not already embodied in preferred utilization, that is correlated with full utilization. Because preferred and practical utilization rates are highly correlated, using both utilization rates would cause a multicollinearity problem that may obfuscate the relationship between preferred and full utilization.

The results of the regressions are presented in Table 9. With a few exceptions, most of the coefficients on preferred utilization (β_1) are estimated to be near 1, in line with our working assumption. In the case of manufacturing, β_1 is 1.02. In most of the two-digit industries, β_1 is in the .98-1.05 range.[11]

To test the relationship between rates, I set the null hypothesis that the coefficient of practical residuals (β_2) equals zero. I then perform a joint test by adding to the null hypothesis the restriction that β_1 equals one. The results of these tests are shown on the right-hand-side of Table 9.

The results of the first set of hypothesis tests, testing whether β_2 equals zero, reject the null in only one instance–Industry 35. These hypothesis tests, like most, are set to reject the null at the five percent level. The five percent significance level, or the size of the test, equals the probability of rejecting a null hypothesis that is true–a type I error (See Greene [1997]). Given that I can only reject the null hypothesis in one of twenty separate regressions, the results of Industry 35 are viewed as a statistical anomaly and given little weight. In summary, there is little evidence that the practical residual plays any significant role in explaining full utilization.

Turning to the joint tests, we can reject, at the 5 percent level, the null hypothesis that β_1 is one and β_2 is zero for only a few industries. In these instances, the results appear to suggest that full utilization is running higher than preferred, suggesting the converse relationship of the one originally supposed. Initially, the main objective of this study was to determine whether full utilization actually aligns with practical utilization and is lower than preferred utilization. As described earlier in this paper, some changes to survey assumptions may have the effect of depressing reported capacity and boosting utilization. In most cases, however, full utilization does not appear to be significantly greater than preferred.

Having already discounted the results of industry 35, four industries reject the joint hypothesis test. For Industries 24 and 34, I cannot reject an additional test that the null hypothesis that β_1 equals 1.01 and β_2 equals zero; one cannot reject a level shift that is of the order of only 1 percent. Even so, practical utilization still adds nothing to the predictive

[11]For the sake of space constraints and because Industry 29 is the only two-digit industry with utilization estimates based on trade data and not the SPC, I do not report its results any further.

power. For these two industries, the economic significance of the results still seem in line with the general tenor of the results.

In industries 37 and 38, β_1 is also significantly different from one. Returning to Figure 23, it appears that the estimates of full utilization consistently sits above the preferred utilization rate in Industry 37. Industry 37 is also noteworthy as the two-digit industry with the highest concentration of variable work period establishments [see Table 7]. Moreover, the Federal Reserve uses trade association data for portions of this industry. In the case of Industry 38, shown in Figure 24, full utilization does line up closely with preferred utilization in some years. In all, further analysis, possibly with the available trade data, may be warranted for these two industries.

Overall, the results provide no evidence to support a closer relationship between full and practical utilization than previously assumed in official Board statistics. Moreover, there is no evidence that practical utilization provides any additional explanatory power once one considers preferred utilization. The hypothesis tests shown in Table 9 are unambiguous in this regard. The majority of the results support the assumption that full and preferred utilization have a one-to-one relationship.

8 Alternative Approach

To provide further evidence that the results described above are robust, I present a different empirical approach with the same ultimate goal, estimating full production. The panel regressions included all data for 1989-1994 period, and used the coefficients to predict full production in the 1976-88 period. The usable set of explanatory variables was constrained to the variables that were available throughout the 1976-94 period. With a cross-sectional specification, I am able to take advantage of a larger set of explanatory variables. However, the alternative approach has the disadvantage of using an isolated time period, rather than capturing capacity behavior at different points in the business cycle. The general conclusions regarding full production are not altered with information based on the estimates of full production constructed with this alternative specification.

With this alternative approach, I focus on the time period when the survey change occurred–1988 and 1989 and utilize the cross-sectional variation for the plants that responded to both versions of the survey. The alternative approach includes regressions for full production in 1989. On the right hand side, I include 1989 and 1988 variables, including the lagged values for both preferred and practical capacity. I also include dummy variables on expansion plans, the dummy variables on changes to capital stock, and the additional variables described in the bottom portion of Table 6.

Once I have controlled for the previous year's capacity measures, I am estimating the change in capacity from year $t-1$ to year t while simultaneously trying to capture the definitional change. The two capacity measures in 1988 are quite collinear; multicollinearity convolutes the respective coefficients, making a strict interpretation problematic. Despite difficult interpretations of the coefficients, the predicted values for full production are quite valid. The empirical results, presented in Table 10, illustrate that the explanatory power of the regression is good, with R-squares ranging from .74 to .88.

To analyze the results, I aggregate the predicted values in the same manner described in the previous section. Using these aggregate values for manufacturing, Figure 26 also suggests that full production and preferred operations align closely. In sum, though, the results of this alternative approach are consistent with the results implied by the panel regressions.

9 Conclusion

An important goal in the construction of capacity utilization rates is to produce a measure that is consistent over time. The object of this study has been to carefully examine the change in the SPC in 1989, an important discontinuity in the source data used to generate the official estimates of manufacturing utilization. The SPC was revamped in many dimensions making it unclear what the ultimate effect on the survey results would be. In light of this, the question of linking the old measures of utilization with the new measures is an empirical question.

The preponderance of results presented in this study provide no evidence suggesting that practical utilization is better aligned with full utilization.

A contact at Census reports that these findings are reasonable.[12] When the new version of the survey was implemented, the staff at Census who manage the capacity survey expected full utilization to fall between practical and preferred utilization. Nonetheless, the one-to-one relationship between full and preferred was within the range of their expectations.

In sum, the results of this study, based on simple summary statistics and on various empirical analysis, suggest that full utilization aligns most closely with preferred utilization. Thus, the findings are consistent with assumptions underlying current methodology employed by the Federal Reserve to calculate capacity utilization.

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References

Berndt, Ernst R. and Morrison, Catherine J. (1981), "Capacity Utilization Measures: Underlying Economic Theory and an Alternative Approach," *American Economic Review: Papers and Proceedings*, 71: 48–52.

Beaulieu, J. Joseph and Mattey, Joe. (1995), "The Workweek of Capital and Capital Utilization in Manufacturing," *Proceedings of the 1995 Annual Research Conference*, U.S. Bureau of the Census.

Christiano, Lawrence J. (1981), "A Survey of Measures of Capacity Utilization," *International Monetary Fund Staff Papers*, 28.

Corrado, Carol and Kortum, Samuel. (1995), "Perspectives on Manufacturing Capacity Growth", Mimeo.

Corrado, Carol and Mattey, Joe. (1997), "Capacity Utilization", *Journal of Economic Perspectives*, 11: 151–67.

de Leeuw, Frank. (1979), "Why Capacity Utilization Rates Differ," *Measures of Capacity Utilization: Problems and Tasks*, Federal Reserve Board of Governors.

Forest, Lawrence R., Jr. (1979), "Capacity Utilization: Concepts and Measurement," *Measures of Capacity Utilization: Problems and Tasks*, Federal Reserve Board of Governors.

Greene, William H. (1997), *Econometric Analysis* (third edition), Macmillan: New York.

Klein, Lawrence R. (1960), "Some Theoretical Issues in the Measurement of Capacity," *Econometrica*, 28: 272-286.

Klein, Lawrence R. and Long, Virginia. (1973), "Capacity Utilization: Concept, Measurement and Recent Estimates," *Brookings Papers*, 3: 743-56.

Mattey, Joe and Strongin, Steve. (1994), "Factor Utilization and Margins for Adjusting Output: Evidence from Manufacturing Plants," Mimeo.

McGuckin, Robert and Zadrozny, Peter. (1988), "Long-Run Expectations and Capacity," CES Working Paper 88-1, Bureau of the Census.

Mohr, Michael F. and Morin, Norman. (1998), "The Dimensions of Capital and the Sources of Capacity Growth in U.S. Manufacturing Industries: Preliminary Results from Recent Research," Draft.

Schnader, Marjorie H. (1984), "Capacity Utilization," *Handbook of Economic and Financial Measures*, Dow Jones-Irwin: Homewood IL, 74–104.

Sudman, Seymour, Bradburn, Norman and Schwarz, Norbert. (1996), *Thinking about Answers*, Jossey-Bass: San Francisco.

Schwarz, Norbert and Sudman, Seymour. (1996), *Answering Questions*, Jossey-Bass: San Francisco.

U.S. Department of Commerce (various years), *Current Industrial Reports: Survey of Plant Capacity*, Bureau of the Census: Washington D.C.

Winston, Gordon C. (1977), "Capacity: An Integrated Micro and Macro Analysis." *American Economic Review: Papers and Proceedings*, 67: 418–21.

Table 1: Capacity Definitions

Capacity Measure	Definition	Time Period
Practical Capacity	The maximum level of production that this establishment could reasonably expect to attain using a realistic employee work schedule and the schedule and the machinery and equipment in place during the time periods covered by this survey.	1974-88
Preferred Operations	A level of operations that you would prefer not to exceed because of costs or other considerations. Implicit in the idea of a preferred level of is that there is a level of operations at which profits are maximized (where marginal revenue equals marginal costs). The preferred level may equal *but not exceed practical capacity.*	1974-88
Full Production	The maximum level of production that this establishment could reasonably expect to attain under normal operating conditions.	1989-present

Notes: The definitions are provided in the Department of Commerce's annual SPC reports.

Table 2: Assumptions Used in Computing Capacity Estimates

Assumption	Preferred	Practical	Full
1) Do not consider overtime pay, availability of labor, materials, utilities, etc. to be limiting factors.		x	x
2) Assume a product mix that was typical or representative of your production during the current quarter. If your plant is subject to considerable short-run variation assume the product mix of the current period.	x	x	x
3a) Assume the number of shifts and hours of plant operation that can be reasonable attained by your plant in your community.	x	x	
3b) Do not assume number of shifts and hours of plant operations under normal conditions to be higher than that attained by your plant over the last five years.			x
4) Consider only the machinery and equipment in place and ready to operate. *Do not* consider facilities or that would require extensive reconditioning before they can be made operable.	x	x	x
5) Assume normal downtime, maintenance, repair and cleanup.	x	x	x
6) Do not assume increased use of production facilities outside the plant in excess of the proportion that would be normal during the time period covered by this survey.	x	x	x
7) Assume the availability of labor, materials, utilities, etc., sufficient to utilize the machinery and equipment that was in place at the end of the year.	x	x	

Notes: The definitions are provided in the Department of Commerce's annual SPC reports.

Table 3: Comparison of Capacity Measures

	Actual ≠ Preferred = Practical	Actual ≠ Preferred < Practical	Actual = Preferred = Practical	Actual = Preferred <Practical
All Mfg	53.8	46.2	11.6	6.6
Continuous	74.4	25.5	16.5	4.7
Variable	48.6	51.4	9.0	4.2
Other	53.1	46.9	13.3	5.2
Year:				
1974	30.8	69.2	6.5	4.6
1978	59.1	40.9	15.5	4.0
1983	57.4	42.6	10.4	4.7
1988	55.8	44.2	14.7	4.8

Notes: Author's tabulations using the SPC. Columns may not add to 100 percent due to rounding.

Table 4: Principal Reasons Operations Fell Short of Preferred Operations

Category	No Response	Insufficient Orders	Inadequate Labor Force	Lack of Materials	Weather
All Mfg	9.9	62.3	5.8	8.3	9.6
Continous	11.8	58.1	0.7	5.3	20.3
Variable	9.7	62.1	6.0	9.7	8.4
Other	9.5	64.0	7.4	7.5	7.6

Notes: The second column provides a factor by which the displayed figures should be scaled to give actual estimates. For example, a displayed coefficient of 1.16 and a scale factor of 10^{-2} implies an estimated coefficient of 0.0116. **Significant at the five percent level in a two-tailed test. *Significant at the ten percent level in a two-tailed test.

Table 5: Comparison Across Surveys for Plants that Reported in 1988 and 1989

Utilization Rates	Mean	Std. Dev.
U-Full Production (1989)	0.83	0.16
U-Preferred Operations (1988)	0.86	0.17
U-Practical Capacity (1988)	0.80	0.19
Ratios:		
$\frac{U-Full(1989)}{U-Preferred(1988)}$	1.00	0.48
$\frac{U-Full(1989)}{U-Practical(1988)}$	1.08	0.51

Notes: Author's tabulations using the SPC.

Table 6: Variable List for Panel Regressions

$CAPSEQUAL$	– dummy var equals 1 when preferred = practical
$TECHCLASS$	– categorical var splitting plants by technical class
$MAX\ P_{t-2}$	– plant's max output over period 1974 to t-2 ($)
$P_{t-1} - MAX\ P_{t-2}$	– plant's production in previous year ($)
$NPWE$	– plant's non-production workers
TE	– plant's total employment
$PLTSHIP_{t-1}$	– plant's shipments in previous year ($)
$\%INDSHIP$	– industry shipments, pct chg from previous year ($)
$COST\ of\ K$	– cost of capital
$\Delta CAP(BLDG\ INVEST)$	– cap change (building expenditures)
$\Delta CAP(MACH\ INVEST)$	– cap change (machinery expenditures)
$\Delta CAP(BLDG\ RETIRE)$	– cap change (building retirements)
$\Delta CAP(MACH\ RETIRE)$	– cap change (machinery retirements)
$\Delta CAP(OPERATIONS)$	– cap change (change in meth of op)
$\Delta CAP(CHG\ PROD\ MIX)$	– cap change (change in product mix)
$\Delta CAP(CHG\ INPUTS)$	– cap change (change in inputs)
$\Delta CAP(OTHER)$	– cap change (other)
$TIME\ TREND$	– time trend starting in 1974
$(x) * I_+$	– interactive term equal to 1 when $x > 0$
Additional Variables used in Alternative Specifications	
$ACTHOURS$	– plant hours per day in operation
$ACTDAYS$	– days per week in operation
$MKTSHARE$	– percent market share
$PLANTAGE$	– plant age in years
$PWHHOURS$	– hours worked by production workers
$PREFOPER$	– preferred operations ($)
$PRACCAP$	– practical capacity ($)

Table 7: Breakdown of Industries by Technical Class

Industry (SIC)	% Continuous (TClass 1)	% Variable (TClass 2)
Food (20)	16.1	25.9
Tobacco (21)	0.0	87.5
Textiles (22)	4.4	34.7
Apparel (23)	1.8	28.0
Lumber (24)	0.0	60.8
Furniture (25)	0.0	15.0
Paper (26)	66.7	1.7
Printing (27)	2.7	7.9
Chemicals (28)	80.6	9.2
Petroleum (29)	93.7	0.0
Rubber (30)	0.0	8.4
Leather (31)	0.0	51.8
S.C.G. (32)	44.9	16.7
Prec. Metals (33)	73.7	17.2
Fab. Metals (34)	9.2	63.4
Machinery (35)	0.0	71.5
Elec. Mach. (36)	0.7	74.9
Trans. Equip (37)	0.0	93.4
Instruments (38)	0.0	21.1
Misc. (39)	0.0	24.3

Notes: Data reproduced from Beaulieu and Mattey [1995, p.37].

Table 8: Full Production Regressions with Plant-Level Data

Independent Variable	TClass 1 Coeff.	TClass 1 Std. Err.	TClass 2 Coeff.	TClass 2 Std. Err.	TClass 3 Coeff.	TClass 3 Std. Err.
$MAX\ P_{t-2}$	-0.576**	0.039	0.260**	0.033	-0.727**	0.031
$P_{t-1} - MAX\ P_{t-2}$	0.011	0.026	0.088**	0.027	-0.049**	0.019
$(P_{t-1} - MAX\ P_{t-2}) * I_+$	0.176**	0.049	0.146**	0.046	0.126**	0.041
$NPWE$	-20.7	17.4	-46.8**	5.55	-18.8**	6.25
TE	0.631	0.491	-1.26**	0.360	-0.281	0.266
$\%TE$	21.9**	9.83	41.2**	3.73	16.1**	4.51
$\%NPWE$	-30.5	20.4	-10.3*	6.017	4.89	5.43
$PLTSHIP_{t-1}$	0.079**	0.013	0.132**	0.008	0.148**	0.014
$\%PLTSHIP$	0.040**	0.016	-0.026**	0.011	0.059**	0.014
$(\%PLTSHIP) * I_+$	-0.010	0.028	0.184**	0.015	0.029	0.025
$\%INDSHIP$	0.175	0.281	-0.708**	0.281	-0.105	0.252
$COST\ of\ K$	362**	166	231	279	694**	144
$\Delta CAP(BLDG\ INVEST)$	-4793	4963	-30705**	6292	-4160	3333
$\Delta CAP(MACH\ INVEST)$	8428**	2258	5514	3403	2970	2081
$\Delta CAP(BLDG\ RETIRE)$	-152.3	15876	-49911**	14814	4625	6869
$\Delta CAP(MACH\ RETIRE)$	-4137	6091	3760	8109	-3929	4151
$\Delta CAP(OPERATIONS)$	1377	3707	-1477	4360	-12169**	2630
$\Delta CAP(CHG\ PROD\ MIX)$	-2540	2145	4992	3070	1024	1712
$\Delta CAP(CHG\ INPUTS)$	-5616	5800	24498**	7460	-12183**	4660
$\Delta CAP(OTHER)$	-817.7	1856	-2402	3074	1884	1648
$TIME\ TREND$	8.093	46.37	79.23	58.04	40.41	32.42
$(TIME\ TREND)^2$	42.10**	14.93	9.886	24.63	72.22**	13.51
N	1661		5417		3813	
$R - square$	.31		.16		.34	
$Alt.\ R - square$	.97		.94		.93	

Notes: **Significant at the five percent level in a two-tailed test. *Significant at the ten percent level in a two-tailed test.

Table 9: Regressions of Aggregate Measure of Estimated Full Production

	Estimates				Hypothesis Test	
	Preferred (β_1)		Practical (β_2)			
Industry (SIC)	Coeff.	Std. Err.	Coeff.	Std. Err.	$\beta_2 = 0$	$\beta_1 = 1$ and $\beta_2 = 0$
Food (20)	1.02**	(0.02)	0.13	(0.54)	0.06	1.06
Tobacco (21)	1.01**	(0.04)	-0.11	(0.62)	0.03	0.02
Textiles (22)	1.01**	(0.03)	-1.35	(1.01)	0.20	0.37
Apparel (23)	1.03**	(0.03)	-0.41	(0.99)	0.68	0.61
Lumber (24)	1.03**	(0.01)	0.69	(0.68)	1.03	3.65*
Furniture (25)	0.98**	(0.06)	-0.33	(0.39)	0.73	0.55
Paper (26)	0.98**	(0.02)	1.33	(1.29)	1.08	1.03
Printing (27)	0.99**	(0.01)	-0.74	(0.56)	1.75	1.61
Chemicals (28)	1.01**	(0.02)	-0.02	(0.57)	0.00	0.10
Rubber (30)	0.97**	(0.04)	-.36	(1.16)	0.76	0.79
Leather (31)	0.97**	(0.03)	-0.39	(0.99)	0.16	0.69
S.C.G. (32)	1.04**	(0.04)	-1.39	(0.83)	0.12	0.21
Prec. Metals (33)	1.00**	(0.04)	-0.08	(0.76)	0.01	0.01
Fab. Metals (34)	1.05**	(0.02)	-0.18	(0.26)	0.50	3.94*
Machinery (35)	0.71**	(0.14)	-0.13**	(0.06)	7.23**	10.67**
Elect. Mach. (36)	1.01**	(0.02)	0.14	(0.67)	0.84	0.87
Trans. Equip. (37)	1.07**	(0.02)	-0.46	(0.61)	0.57	5.55**
Instruments (38)	1.06**	(0.02)	0.51	(0.44)	1.36	9.99**
Misc. (39)	1.06**	(0.07)	-0.11	(0.47)	0.05	0.93
Manufacturing	1.02**	(0.02)	0.18	(0.70)	0.79	0.49

Notes: S.C.G. refers to Stone, Clay, Glass. **Significant at the five percent level in a two-tailed test. *Significant at the ten percent level in a two-tailed test.

Table 10: Alternative Full Production Regressions

Independent Variable	TClass 1 Coeff.	TClass 1 Std. Err.	TClass 2 Coeff.	TClass 2 Std. Err.	TClass 3 Coeff.	TClass 3 Std. Err.
$MAX\ P_{t-2}$	0.534*	0.290	0.388**	0.114	0.258**	0.117
$P_{t-1} - MAX\ P_{t-2}$	0.211	0.469	0.546**	0.131	0.157	0.161
$(P_{t-1} - MAX\ P_{t-2}) * I_+$	-0.386	0.407	-0.319**	0.161	-0.211	0.336
$NPWE$	38.8**	18.9	8.60*	4.44	3.59	2.98
$PWHHOURS$	-1.21	1.85	-1.98	2.51	18.8**	2.14
$\%TE$	-32.6	68.1	66.1**	11.4	3.87	18.2
$PLTSHIP_{t-1}$	0.482**	0.233	2.68	0.342	1.03**	0.479
$\%PLTSHIP$	0.386**	0.157	0.048	0.046	0.030	0.103
$(\%PLTSHIP) * I_+$	0.479**	0.224	0.070	0.056	0.003	0.157
$\%INDSHIP$	0.595	5.30	-1.33	1.23	0.023	1.46
$MKTSHARE$	2019*	1095	2994**	1093	624	733
$COST\ of\ K$	661	415	4106	3150	-2409	1670
$ACTHOURS$	-677	3046	0.165	1093	723	589
$\%ACTHOURS$	3097	3472	-672	1376	-1606*	933
$ACTDAYS$	3024	10264	-8068	7770	2259	4256
$\%ACTDAYS$	-4418	17706	12341	9756	7470	5078
$PLANTAGE$	-638	248	-345	289	126	177
$PREFOPER$	-1.31	0.804	1.07**	0.215	-0.534*	0.295
$PRACCAP$	1.63**	0.744	-0.529**	0.145	0.628**	0.293
N	1661		5417		3813	
$R - square$	.88		.82		.74	

Notes: **Significant at the five percent level in a two-tailed test. *Significant at the ten percent level in a two-tailed test.

Table 11: Preferred Operations Regressions with Plant-Level Data

Independent Variable	TClass 1 Coeff.	TClass 1 Std. Err.	TClass 2 Coeff.	TClass 2 Std. Err.	TClass 3 Coeff.	TClass 3 Std. Err.
$MAX\ P_{t-2}$	0.225**	0.049	0.403**	0.024	-1.35**	0.033
$P_{t-1} - MAX\ P_{t-2}$	0.204**	0.035	0.223**	0.020	0.631**	0.033
$(P_{t-1} - MAX\ P_{t-2}) * I_{+}$	-0.222**	0.082	0.491**	0.044	-3.53**	0.040
$NPWE$	12.6	14.1	24.1**	2.32	26.4**	3.54
TE	-2.39**	0.653	0.985**	0.210	0.011	0.258
$\%TE$	-2.19	6.04	-17.5**	1.99	25.3**	3.82
$\%NPWE$	-23.3	16.1	10.5**	3.34	-52.8**	5.21
$PLTSHIP_{t-1}$	0.177**	0.012	0.098**	0.007	0.404**	0.013
$\%PLTSHIP$	0.101**	0.16	0.130**	0.009	0.099**	0.028
$(\%PLTSHIP) * I_{+}$	0.102**	0.032	0.057**	0.013	0.066*	0.040
$\%INDSHIP$	-0.150	0.121	-1.05**	0.096	0.089	0.148
$COST\ of\ K$	-5031**	1314	-1615**	662	-1299*	779
$\Delta CAP(BLDG\ INVEST)$	-5130	8176	3595	4273	4631	4449
$\Delta CAP(MACH\ INVEST)$	12223**	4904	3115	2563	2218	2552
$\Delta CAP(BLDG\ RETIRE)$	-11138	13939	-11400	7484	-9003	11017
$\Delta CAP(MACH\ RETIRE)$	-2472	7490	1636	4853	9907**	5899
$\Delta CAP(OPERATIONS)$	3917	6253	2085	2912	4205	3362
$\Delta CAP(CHG\ PROD\ MIX)$	-6354	3909	-2510	1970	1324	2237
$\Delta CAP(CHG\ INPUTS)$	-3456	8174	-11852**	5025	-4882	5239
$\Delta CAP(OTHER)$	5771	4739	-4251*	2507	184	2756
$TIME\ TREND$	-121	124	-95.6	65.1	-79.5	63.6
$(TIME\ TREND)^2$	64.7*	34.1	55.9**	16.1	212**	18.2
N	1564		9854		5849	

Notes: Regression sample includes all observations where practical capacity does not equals preferred. **Significant at the five percent level in a two-tailed test. *Significant at the ten percent level in a two-tailed test.

Table 12: Preferred Operations Regressions with Plant-Level Data

Independent Variable	TClass 1 Coeff.	TClass 1 Std. Err.	TClass 2 Coeff.	TClass 2 Std. Err.	TClass 3 Coeff.	TClass 3 Std. Err.
$MAX\ P_{t-2}$	0.314**	0.030	0.142**	0.021	-0.567**	0.021
$P_{t-1} - MAX\ P_{t-2}$	0.144**	0.020	-0.295**	0.016	0.737**	0.019
$(P_{t-1} - MAX\ P_{t-2}) * I_{+}$	0.392**	0.053	0.803**	0.038	-2.05**	0.016
$NPWE$	39.6**	8.79	30.5**	3.86	42.4**	4.19
TE	0.316	0.354	0.158	0.237	1.78**	0.28
$\%TE$	-4.14	3.80	-12.6**	2.37	3.21	3.55
$\%NPWE$	14.2	11.2	-16.8**	5.17	10.2*	6.17
$PLTSHIP_{t-1}$	0.163**	0.008	0.154**	0.005	0.291**	0.010
$\%PLTSHIP$	0.032**	0.013	0.143**	0.008	-0.161**	0.028
$(\%PLTSHIP) * I_{+}$	0.077**	0.021	-0.028**	0.011	0.273**	0.039
$\%INDSHIP$	-0.134*	0.079	0.304**	0.124	0.134	0.190
$COST\ of\ K$	-2626**	736	-762	777	-1061	747
$\Delta CAP(BLDG\ INVEST)$	3260	5541	-10946*	5613	2421	4861
$\Delta CAP(MACH\ INVEST)$	623	3234	5036	3141	5511*	2874
$\Delta CAP(BLDG\ RETIRE)$	6692	9394	-18841*	9742	-11076	10235
$\Delta CAP(MACH\ RETIRE)$	-10203**	5071	-3088	6507	-7853	5910
$\Delta CAP(OPERATIONS)$	649	4317	12394**	3603	2162	3663
$\Delta CAP(CHG\ PROD\ MIX)$	-2426	2460	-289	2396	-801	2290
$\Delta CAP(CHG\ INPUTS)$	1044	5394	280	6106	-4835	5892
$\Delta CAP(OTHER)$	-4748*	2793	-8618**	2910	-4957*	2858
$TIME\ TREND$	136*	72.4	40.3	75.3	-151**	62
$(TIME\ TREND)^2$	60.0**	19.7	16.2	20.0	176**	18.5
N	5323		10276		7930	

Notes: Regression sample includes all observations where practical capacity equals preferred. **Significant at the five percent level in a two-tailed test. *Significant at the ten percent level in a two-tailed test.

Table 13: Practical Output Regressions with Plant-Level Data

Independent Variable	TClass 1 Coeff.	TClass 1 Std. Err.	TClass 2 Coeff.	TClass 2 Std. Err.	TClass 3 Coeff.	TClass 3 Std. Err.
$MAX\ P_{t-2}$	0.534**	0.059	0.540**	0.028	-2.14**	0.041
$P_{t-1} - MAX\ P_{t-2}$	0.182**	0.043	0.330**	0.024	0.813**	0.041
$(P_{t-1} - MAX\ P_{t-2}) * I_+$	-0.177*	0.100	0.470**	0.051	-5.11**	0.050
$NPWE$	40.5**	17.2	32.1**	2.70	45.0**	4.38
TE	0.760	0.799	2.60**	0.245	0.996**	0.319
$\%TE$	-28.5**	7.39	-17.7**	2.32	37.3**	4.73
$\%NPWE$	3.30	19.7	8.77**	3.90	-81.0**	6.45
$PLTSHIP_{t-1}$	0.074**	0.014	0.091**	0.008	0.511**	0.016
$\%PLTSHIP$	0.160**	0.019	0.141**	0.010	0.041	0.034
$(\%PLTSHIP) * I_+$	-0.067*	0.039	0.041**	0.015	0.121**	0.050
$\%INDSHIP$	-0.308**	0.148	-1.26**	0.112	0.254	0.183
$COST\ of\ K$	-4877**	1607	-1390*	772	-2165**	963
$\Delta CAP(BLDG\ INVEST)$	6165	9996	4464	4978	5577	5500
$\Delta CAP(MACH\ INVEST)$	11768**	5995	5124*	2985	2468	3155
$\Delta CAP(BLDG\ RETIRE)$	20142	17042	-14633*	8717	-16695	13620
$\Delta CAP(MACH\ RETIRE)$	-27788**	9157	-1456	5652	9307	7293
$\Delta CAP(OPERATIONS)$	15122**	7644	1184	3392	6514	4156
$\Delta CAP(CHG\ PROD\ MIX)$	-6873	4780	-3457	2294	-1607	2766
$\Delta CAP(CHG\ INPUTS)$	-15937	9994	-14941**	5852	-5969	6478
$\Delta CAP(OTHER)$	6088	5794	-6044**	2919	-1485	3408
$TIME\ TREND$	82.3	151	-105	75.8	-155**	78.7
$(TIME\ TREND)^2$	42.1	41.8	77.4**	18.8	350**	22.5
N	1564		9854		5849	

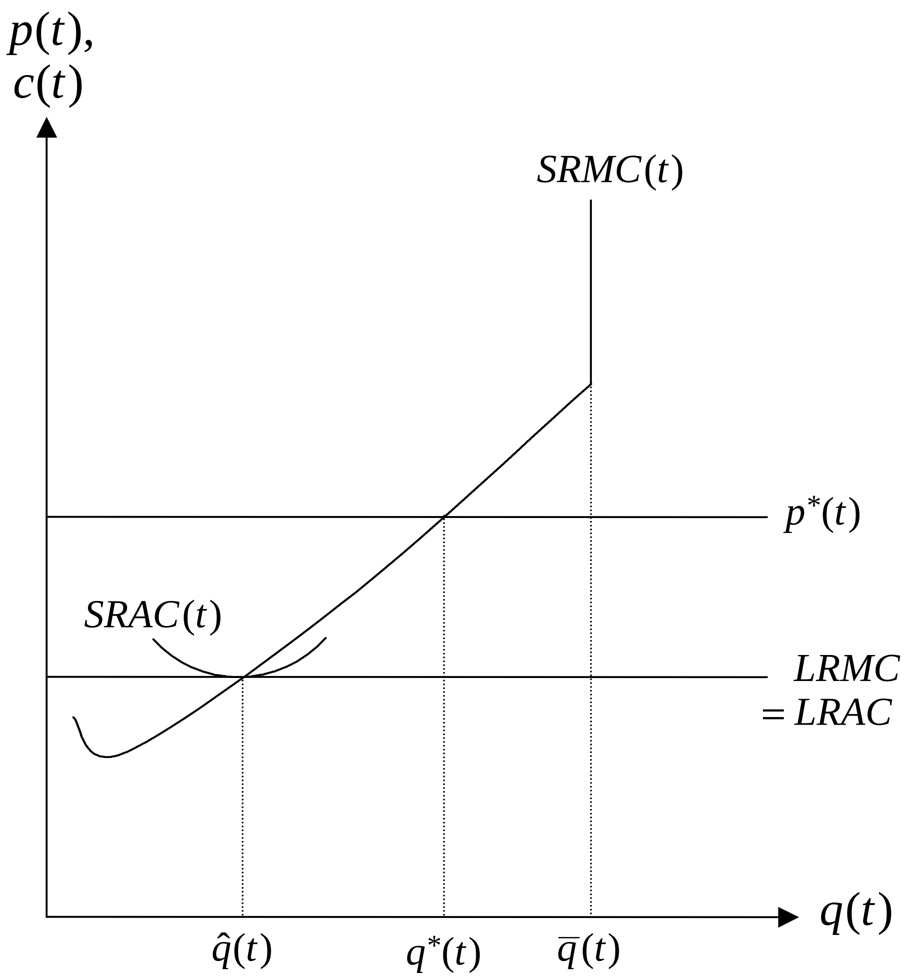
Notes: Regression sample includes all observations where practical capacity does not equals preferred. **Significant at the five percent level in a two-tailed test. *Significant at the ten percent level in a two-tailed test.

Table 14: Practical Output Regressions with Plant-Level Data

Independent Variable	TClass 1 Coeff.	TClass 1 Std. Err.	TClass 2 Coeff.	TClass 2 Std. Err.	TClass 3 Coeff.	TClass 3 Std. Err.
$MAX\ P_{t-2}$	0.343**	0.029	0.149**	0.021	-1.11**	0.023
$P_{t-1} - MAX\ P_{t-2}$	0.116**	0.020	-0.282**	0.016	0.872**	0.020
$(P_{t-1} - MAX\ P_{t-2}) * I_+$	0.424**	0.052	0.778**	0.038	-2.85**	0.018
$NPWE$	50.4**	8.64	33.2**	3.87	47.2**	4.54
TE	-1.06**	0.348	-1.27**	0.237	0.806**	0.306
$\%TE$	-2.86	3.73	-11.4**	2.37	-0.621	3.84
$\%NPWE$	8.95	11.1	-22.4**	5.17	15.41**	6.68
$PLTSHIP_{t-1}$	0.136**	0.008	0.150**	0.005	0.395**	0.011
$\%PLTSHIP$	0.015	0.013	0.140**	0.008	-0.107**	0.030
$(\%PLTSHIP) * I_+$	0.081**	0.020	-0.024**	0.011	0.239**	0.042
$\%INDSHIP$	-0.139*	0.078	0.287**	0.124	0.091	0.206
$COST\ of\ K$	-2374**	724	-702	778	-1656**	810
$\Delta CAP(BLDG\ INVEST)$	2742	5448	-10778*	5619	5153	5266
$\Delta CAP(MACH\ INVEST)$	441	3180	5567*	3144	5325*	3113
$\Delta CAP(BLDG\ RETIRE)$	4979	9237	-18300*	9753	-12891	11089
$\Delta CAP(MACH\ RETIRE)$	-10035**	4986	-2284	6515	-7166	6403
$\Delta CAP(OPERATIONS)$	311	4245	13291**	3607	1912	3969
$\Delta CAP(CHG\ PROD\ MIX)$	-1415	2419	-445	2398	-2274	2481
$\Delta CAP(CHG\ INPUTS)$	6160	5304	406	6115	-5772	6383
$\Delta CAP(OTHER)$	-5328*	2746	-8251**	2914	-5541*	3096
$TIME\ TREND$	103.6	71.3	33.4	75.3	-188**	67.2
$(TIME\ TREND)^2$	62.4**	19.4	18.0	20.1	247**	20.0
N	5323		10276		7930	

Notes: Regression sample includes all observations where practical capacity equals preferred. **Significant at the five percent level in a two-tailed test. *Significant at the ten percent level in a two-tailed test.

Figure 1. Definitions of Capacity**



*Based on Figure 1 of McGuckin and Zadrozny (1988)

Figure 2. Uncertainty and Preferred Capacity

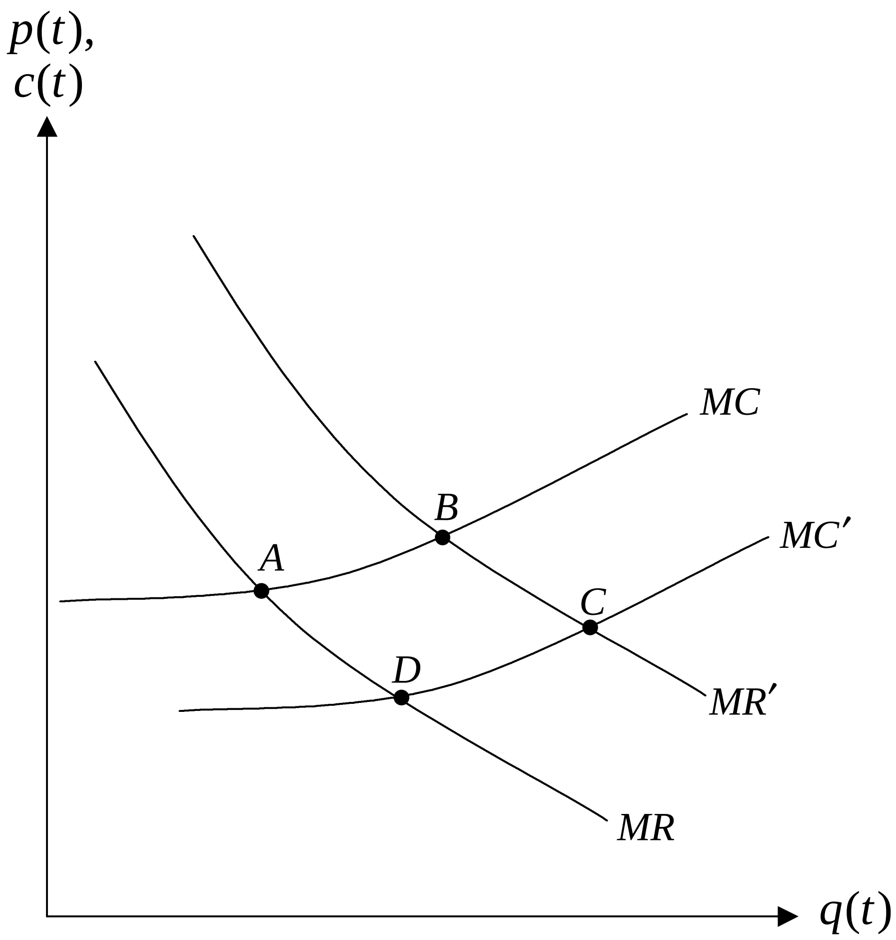


Figure 3. Example of Continuous Processor Plant

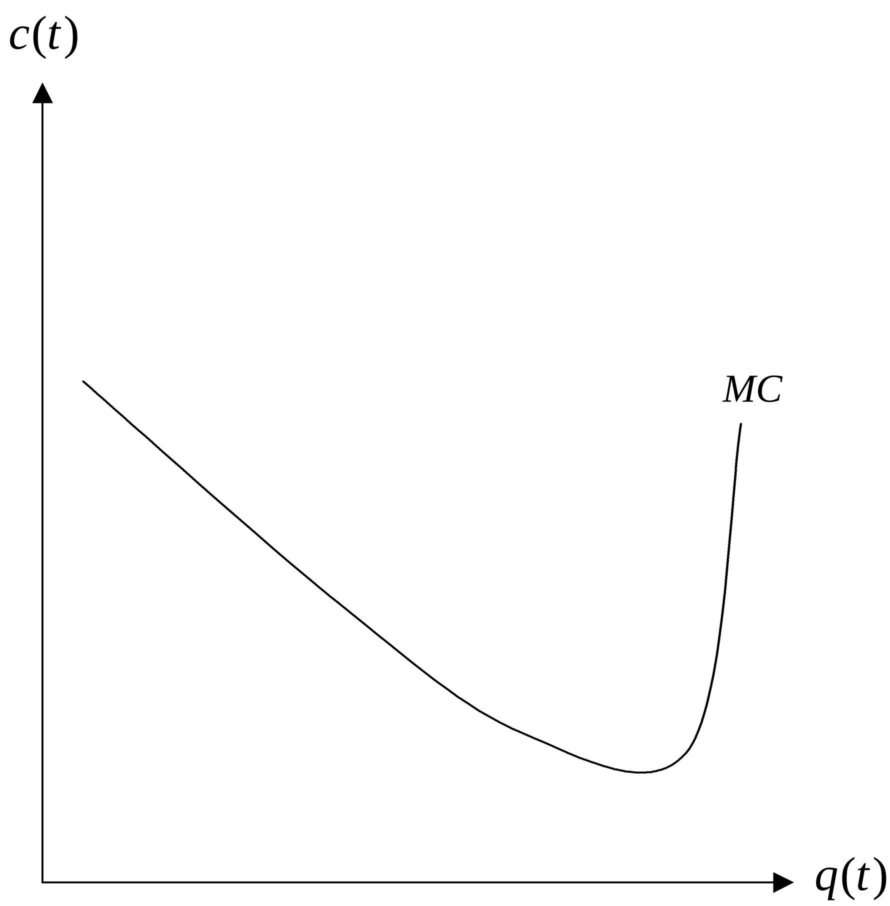


Figure 4: Comparison of Utilization Measures
Manufacturing

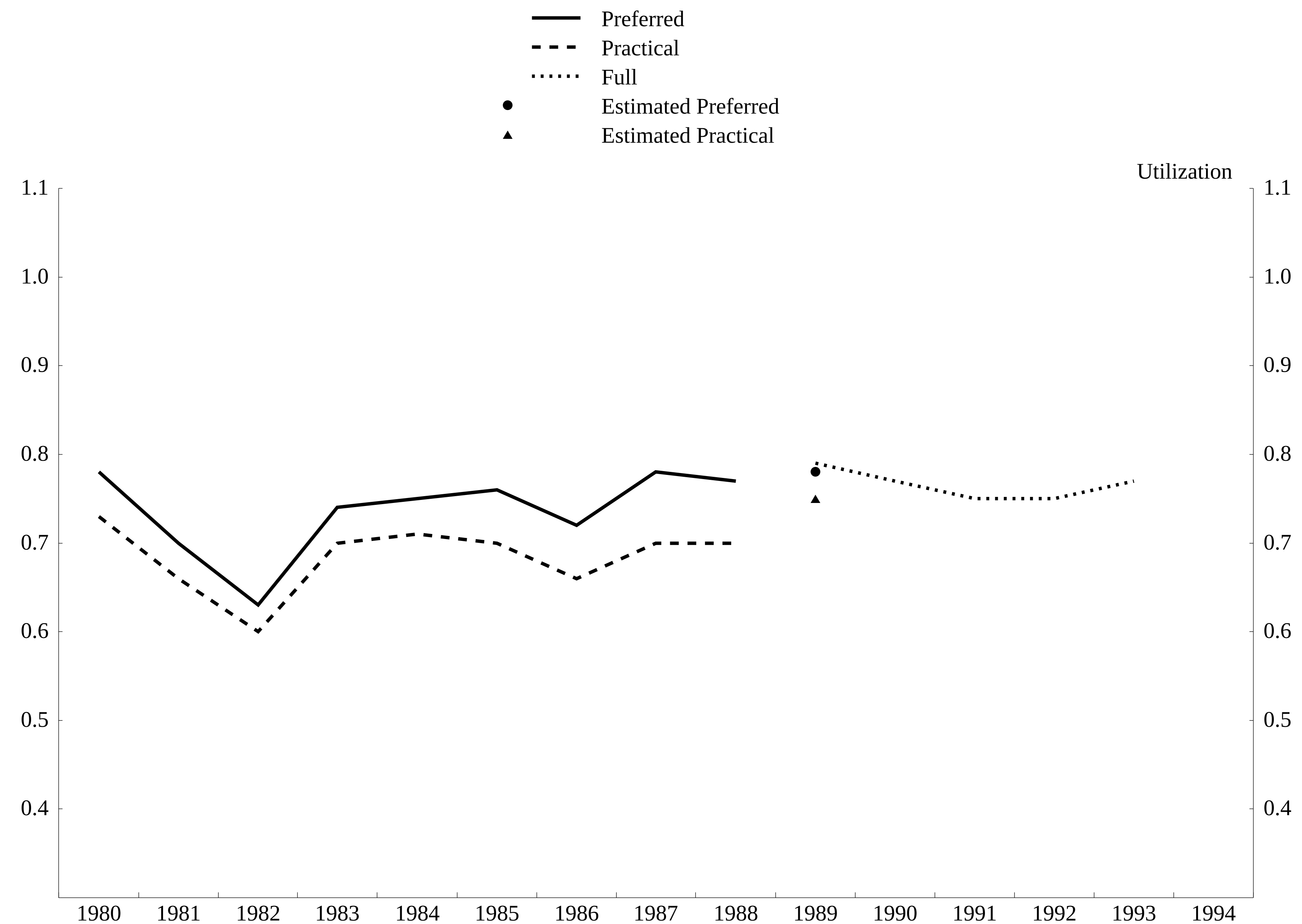


Figure 5: Comparison of Utilization Measures
Manufacturing

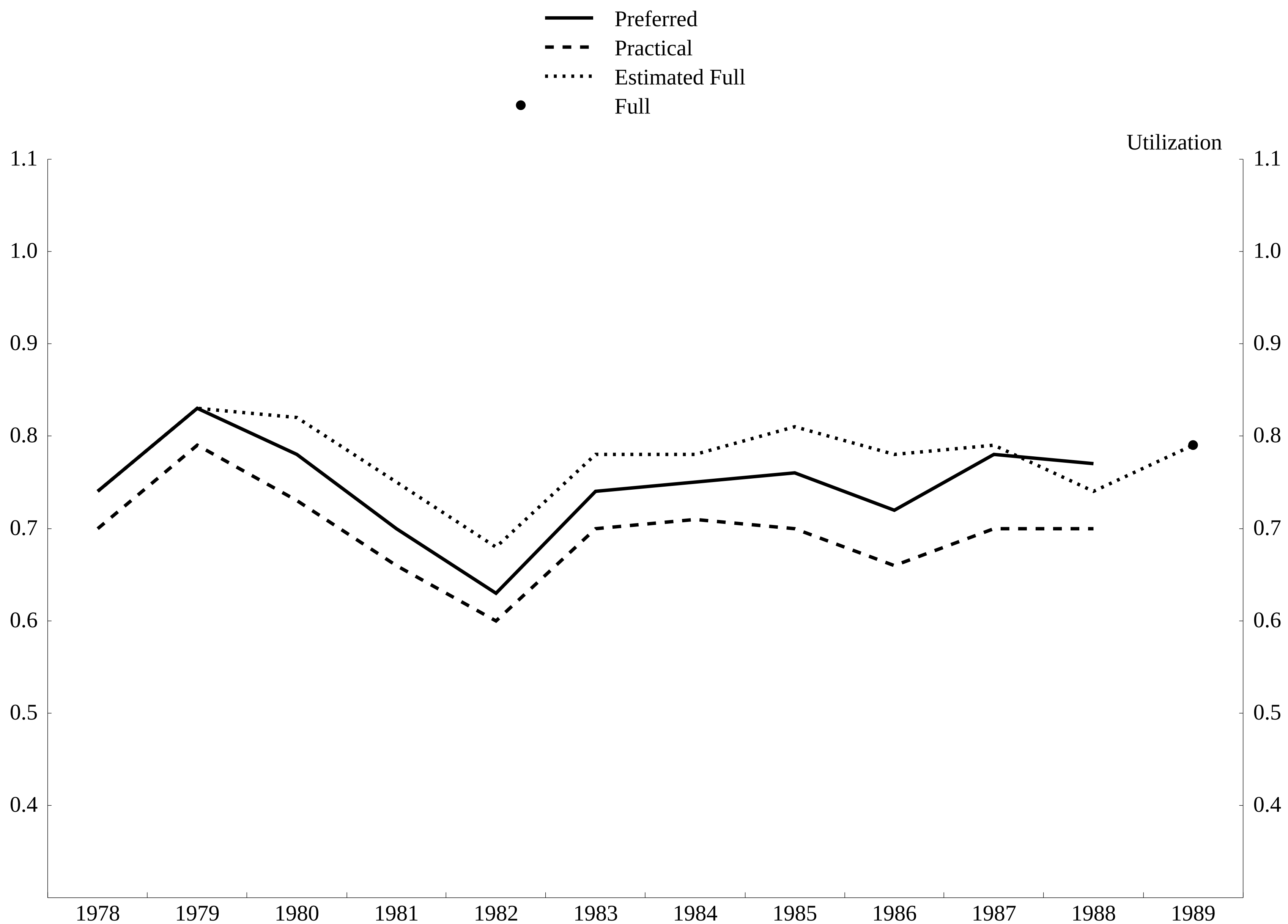


Figure 6: Comparison of Utilization Measures
SIC 20

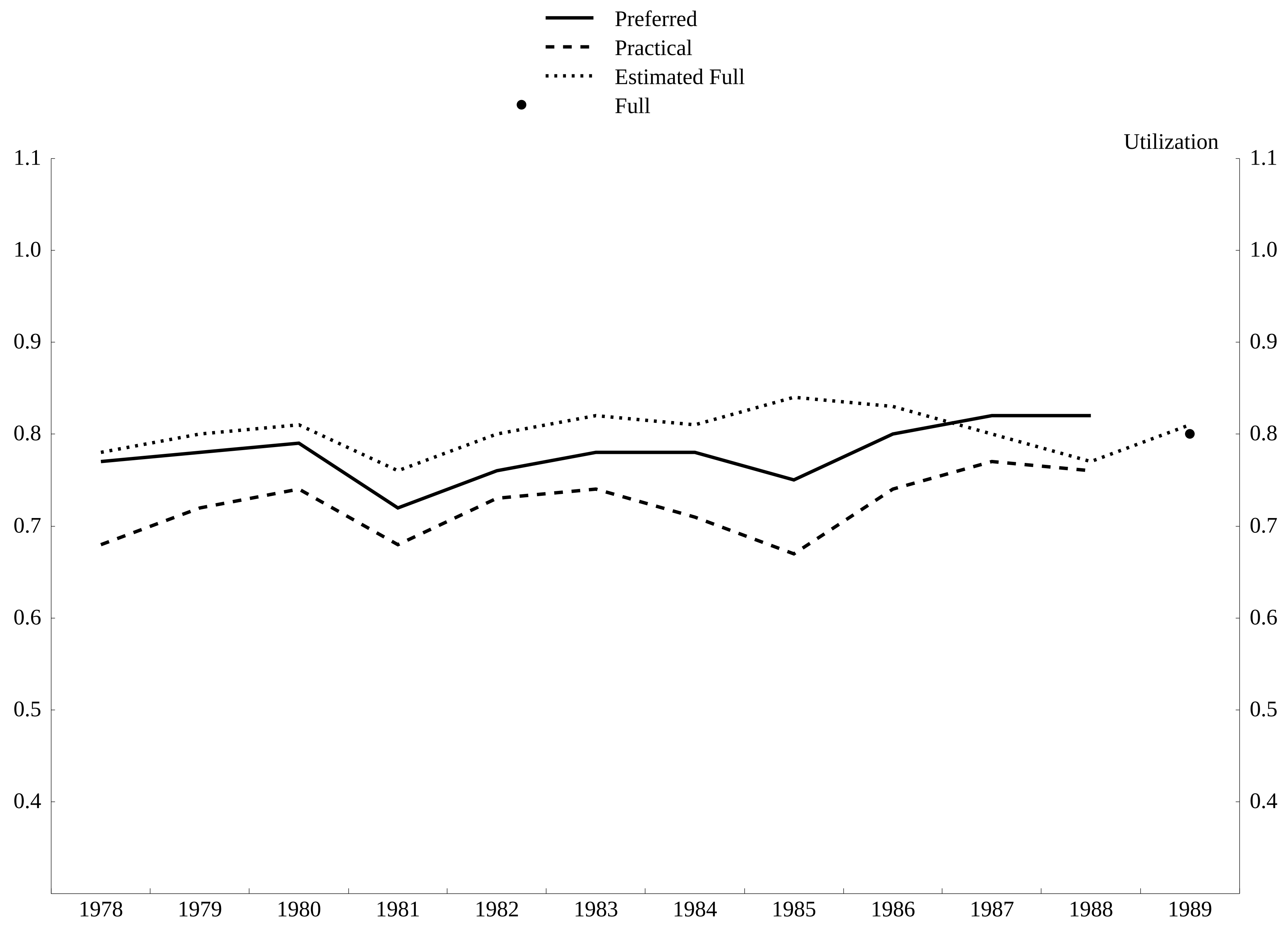


Figure 7: Comparison of Utilization Measures
SIC 21

Figure 8: Comparison of Utilization Measures
SIC 22

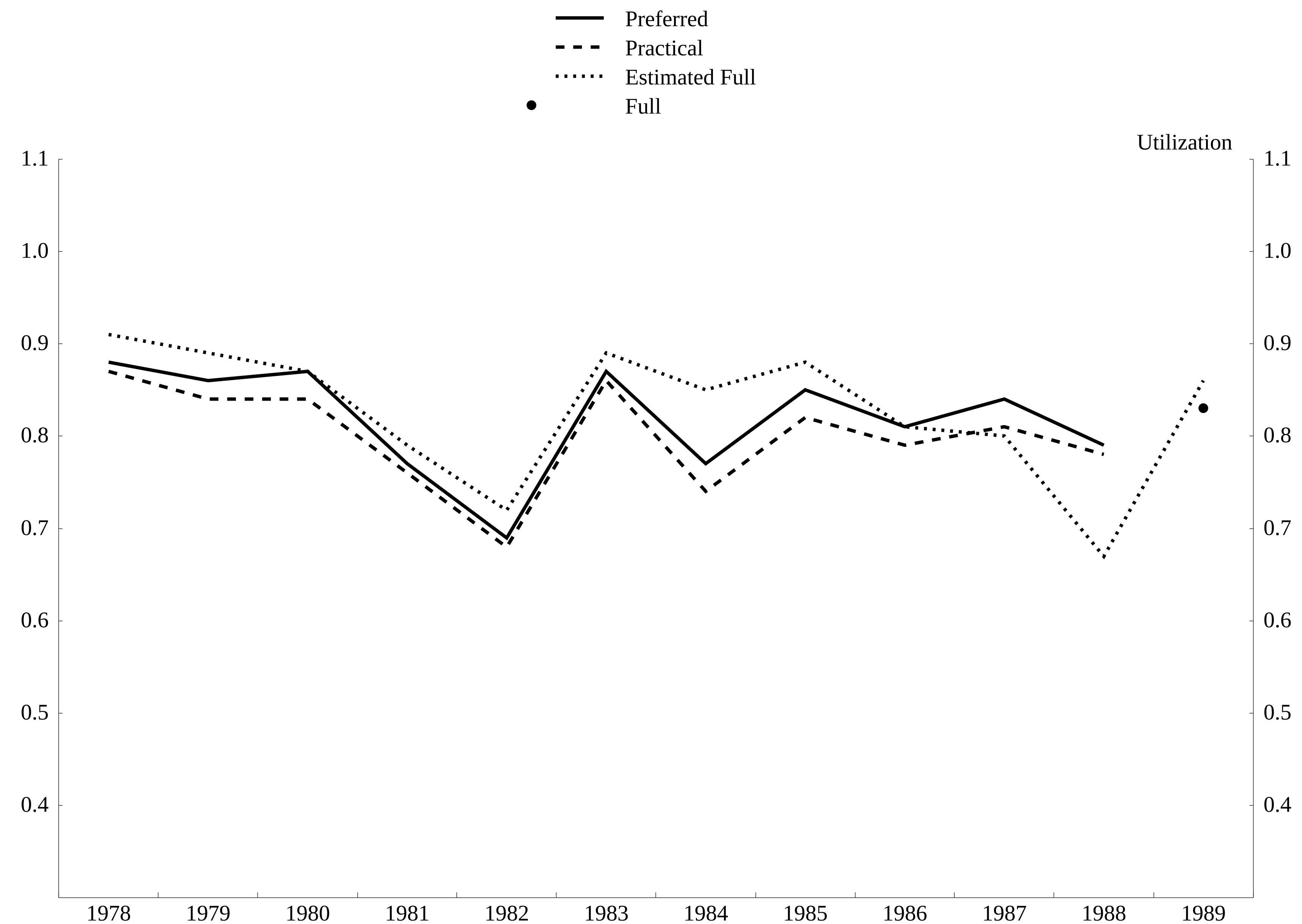


Figure 9: Comparison of Utilization Measures
SIC 23

Figure 10: Comparison of Utilization Measures
SIC 24

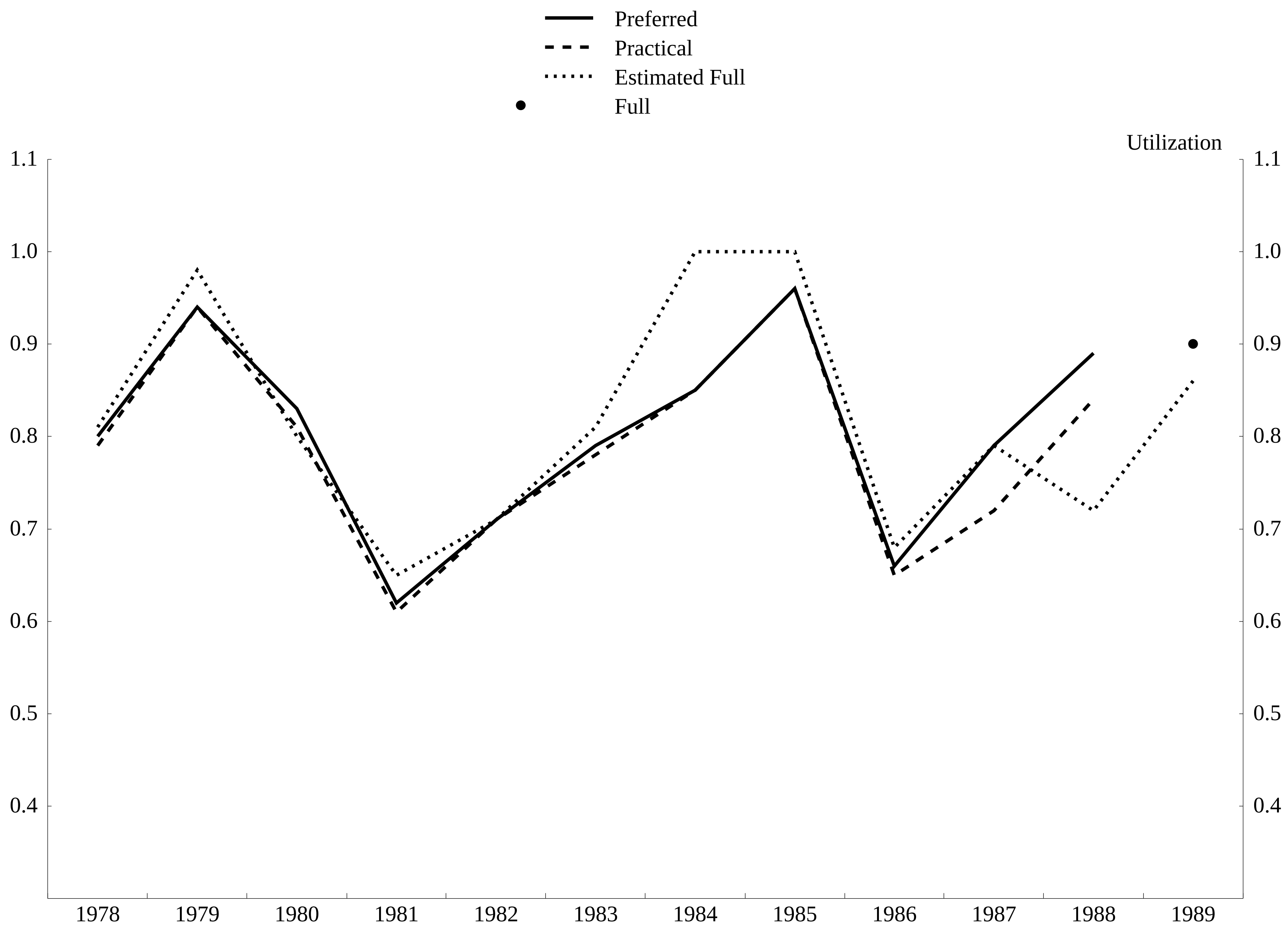


Figure 11: Comparison of Utilization Measures
SIC 25

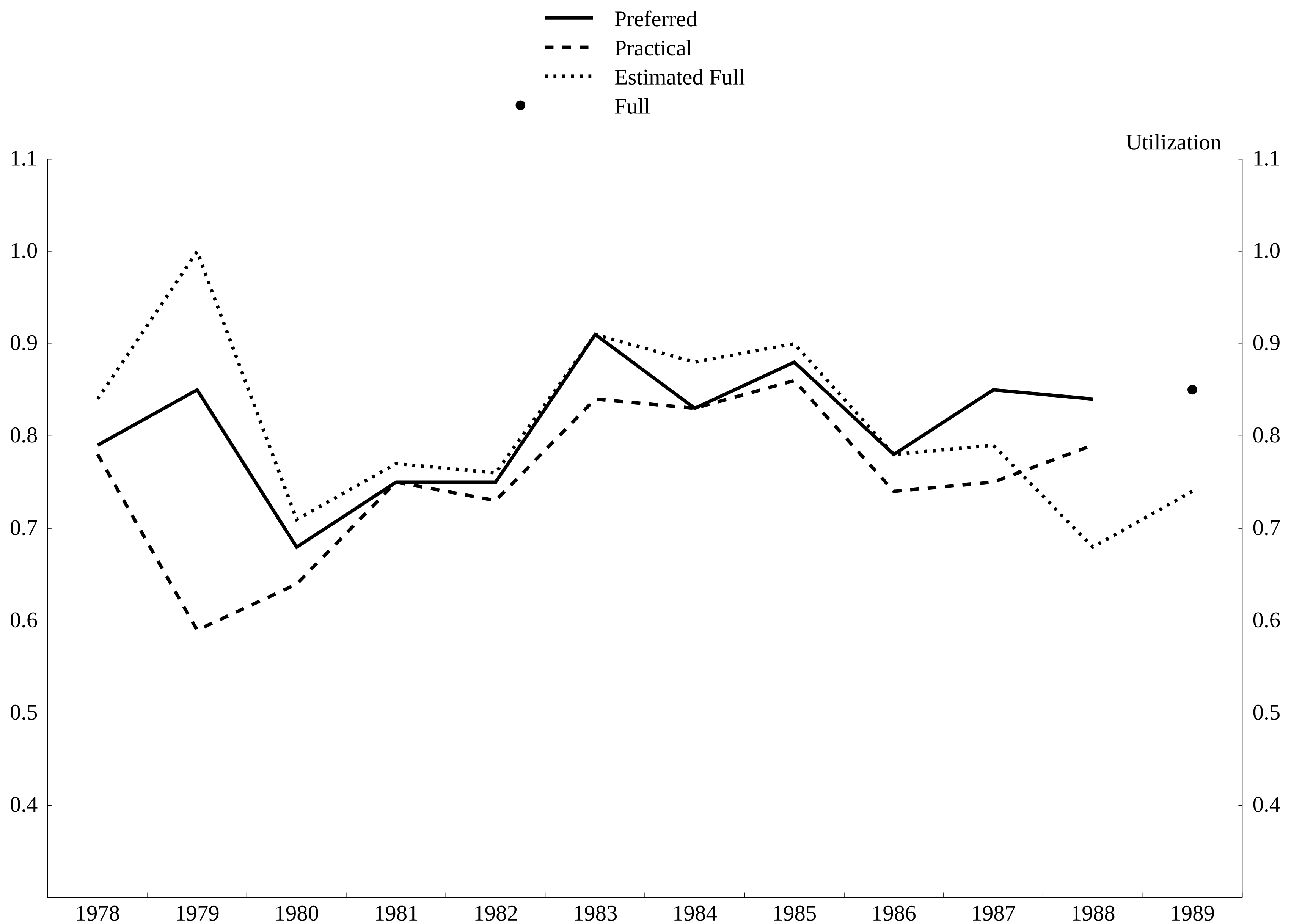


Figure 12: Comparison of Utilization Measures
SIC 26

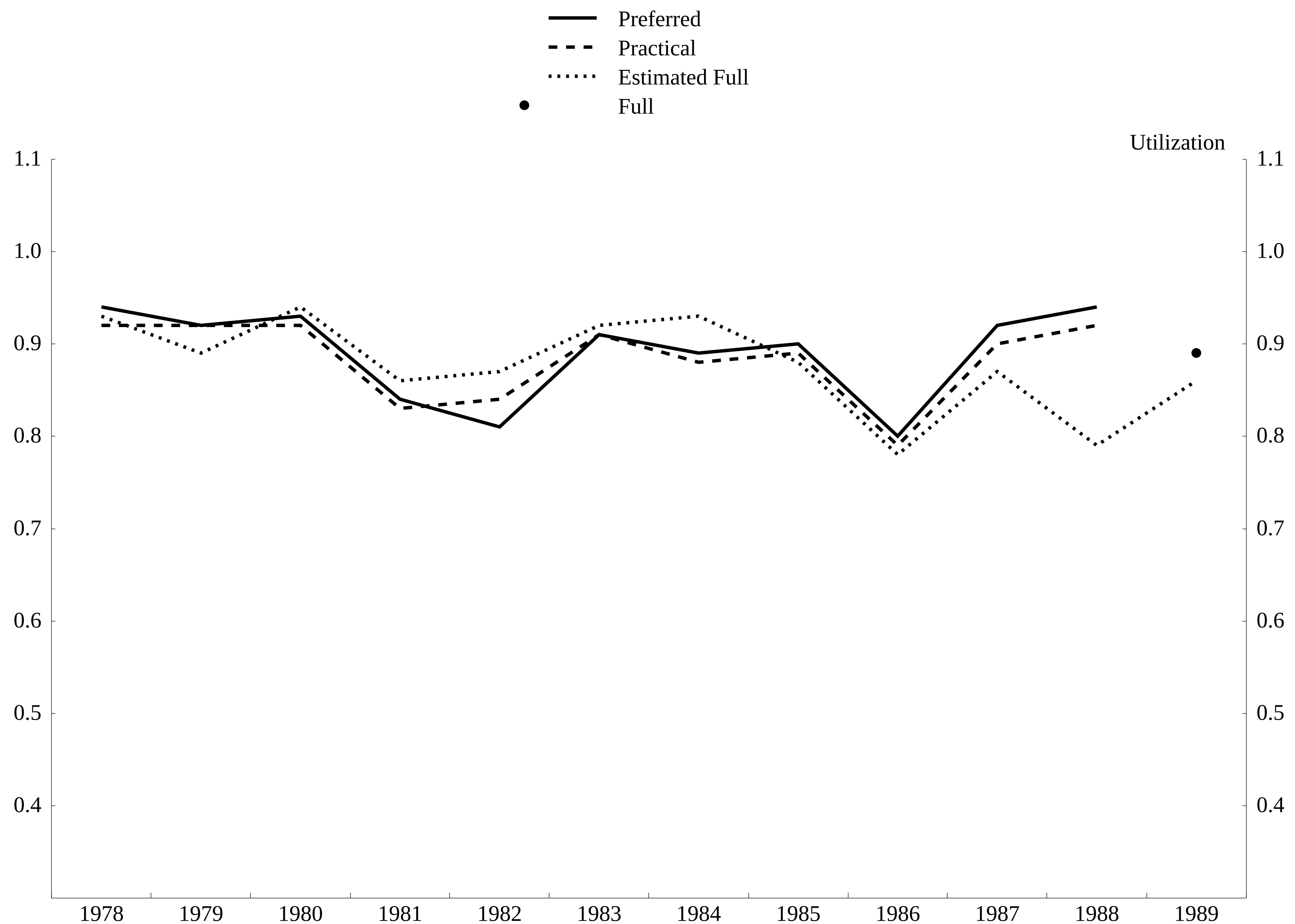


Figure 13: Comparison of Utilization Measures
SIC 27

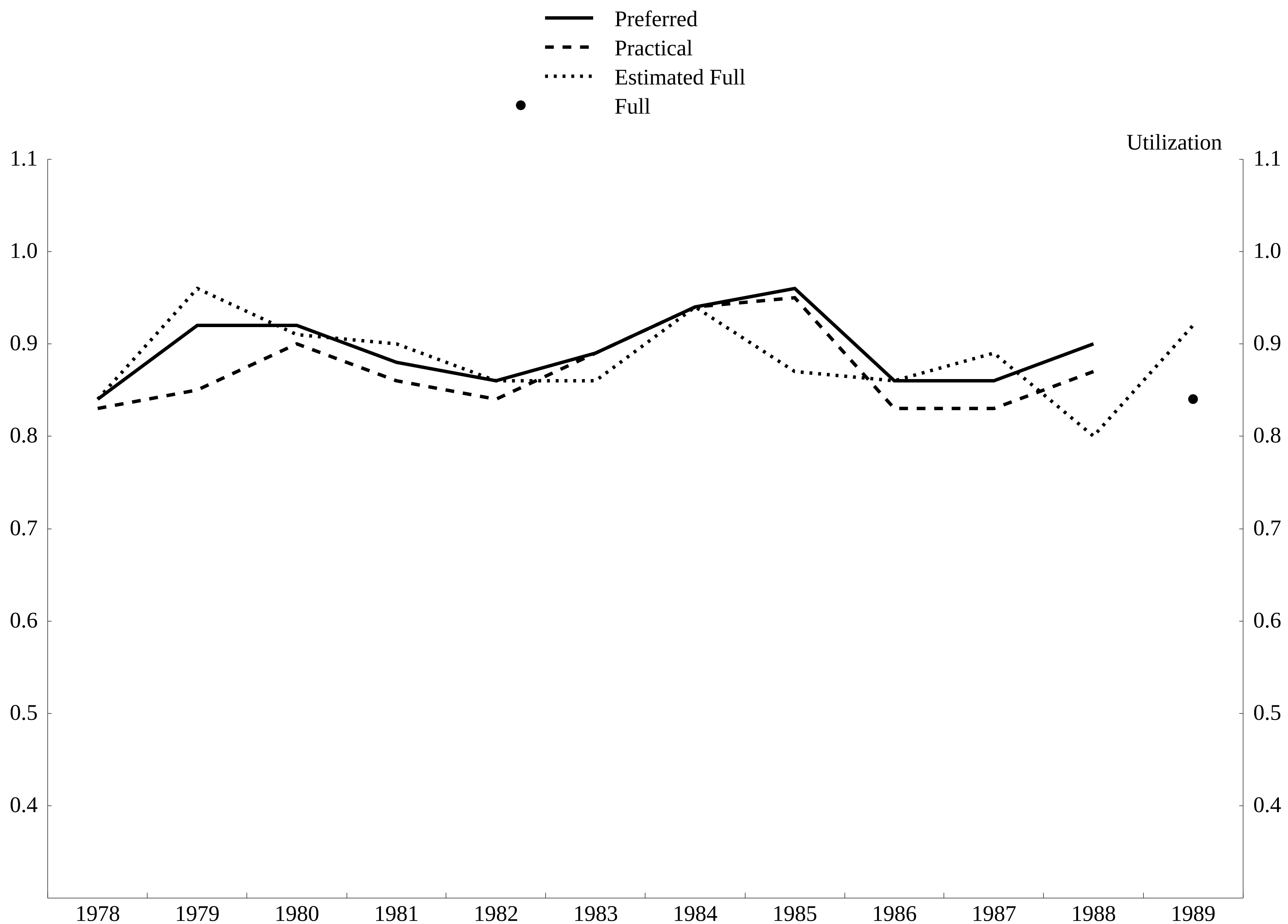


Figure 14: Comparison of Utilization Measures
SIC 28

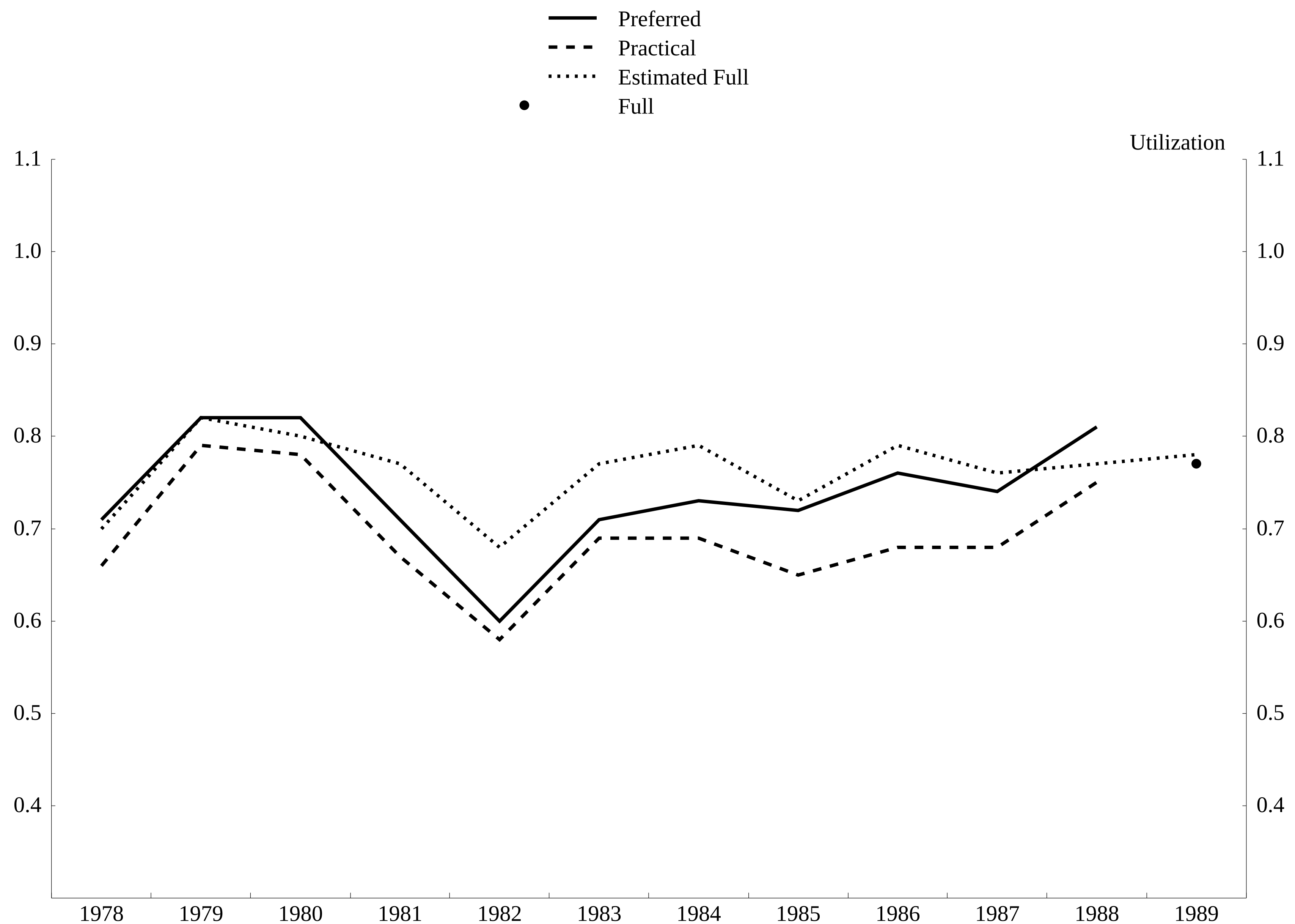


Figure 15: Comparison of Utilization Measures
SIC 29

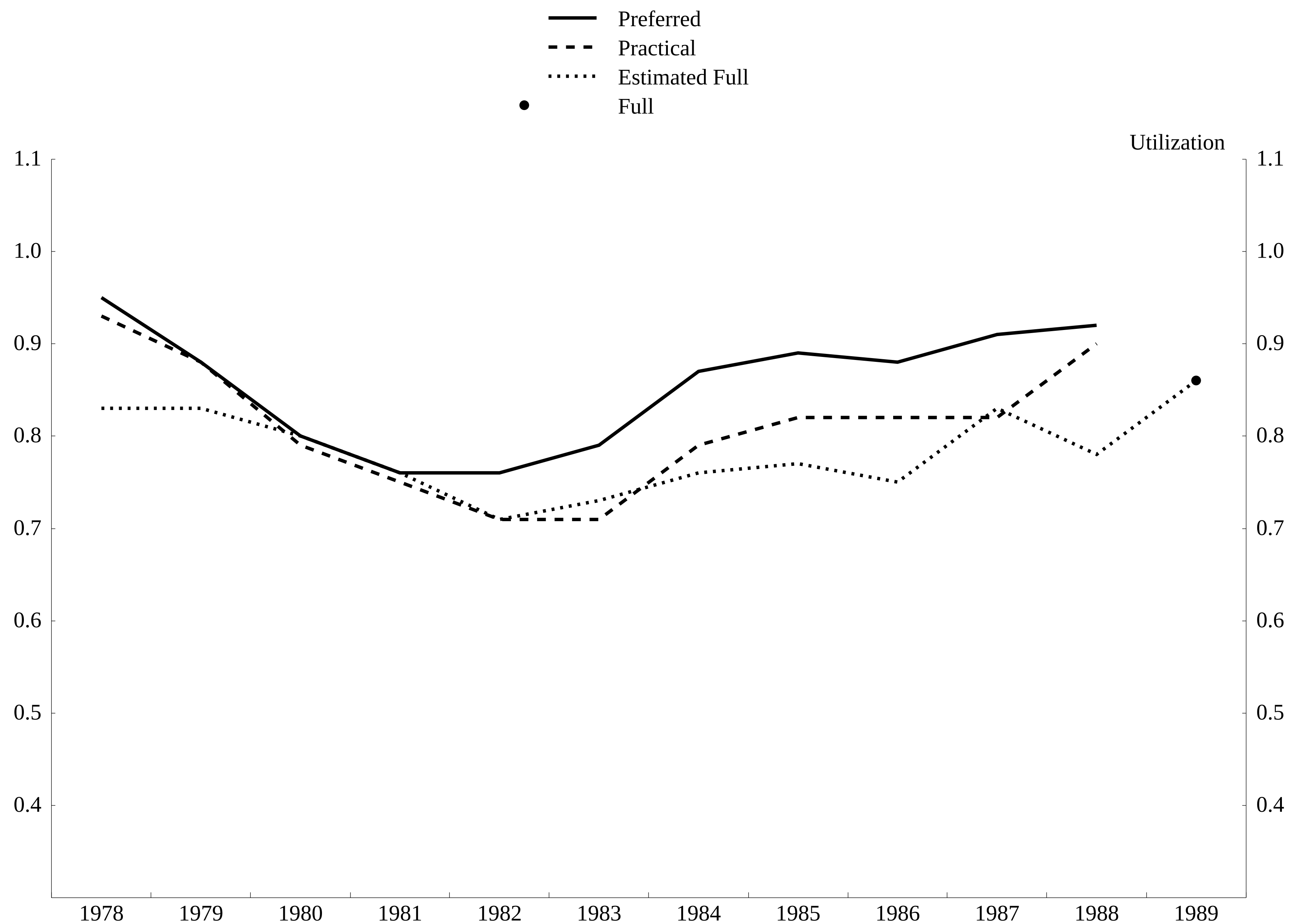


Figure 16: Comparison of Utilization Measures
SIC 30

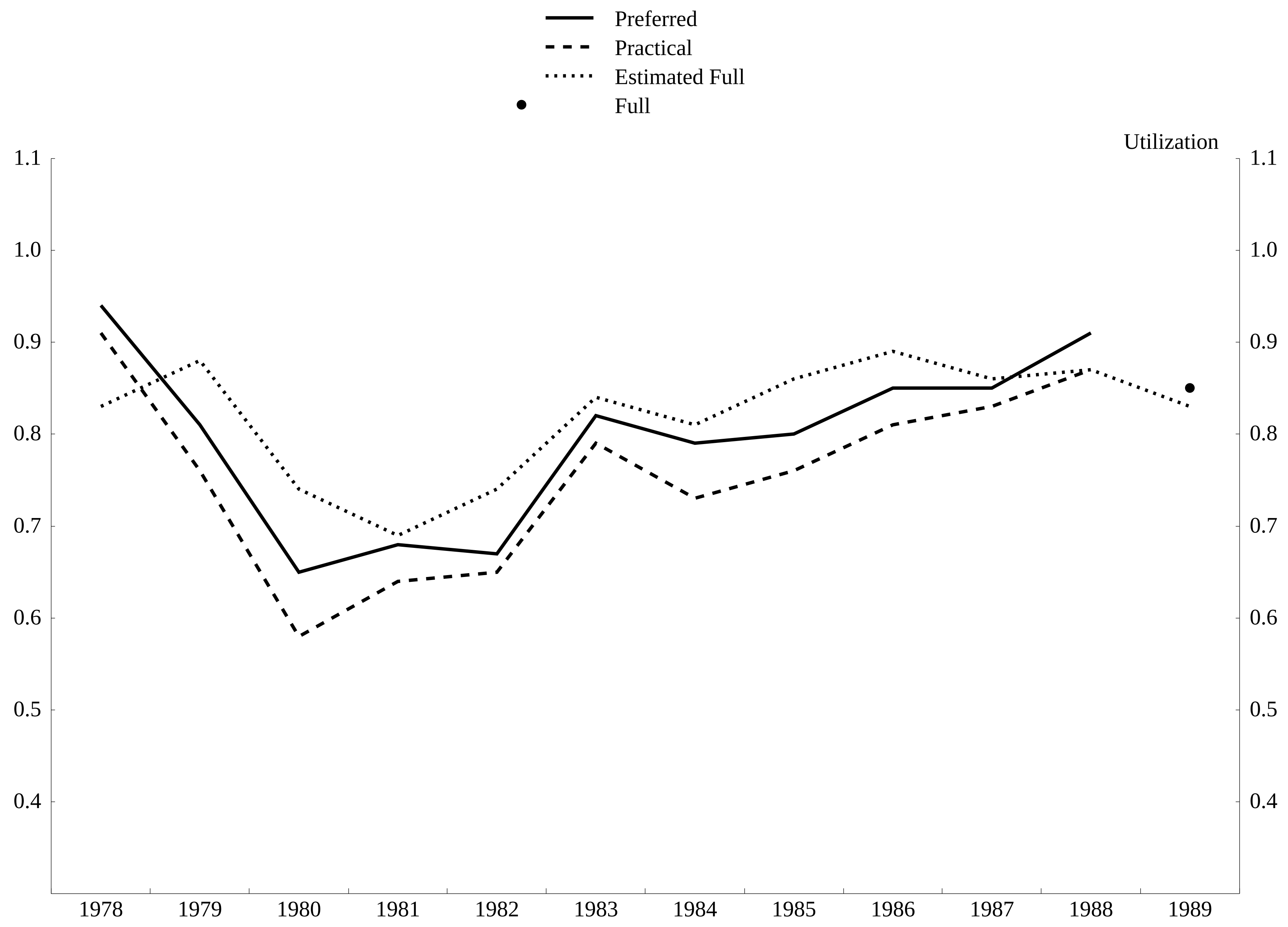


Figure 17: Comparison of Utilization Measures
SIC 31

Figure 18: Comparison of Utilization Measures
SIC 32

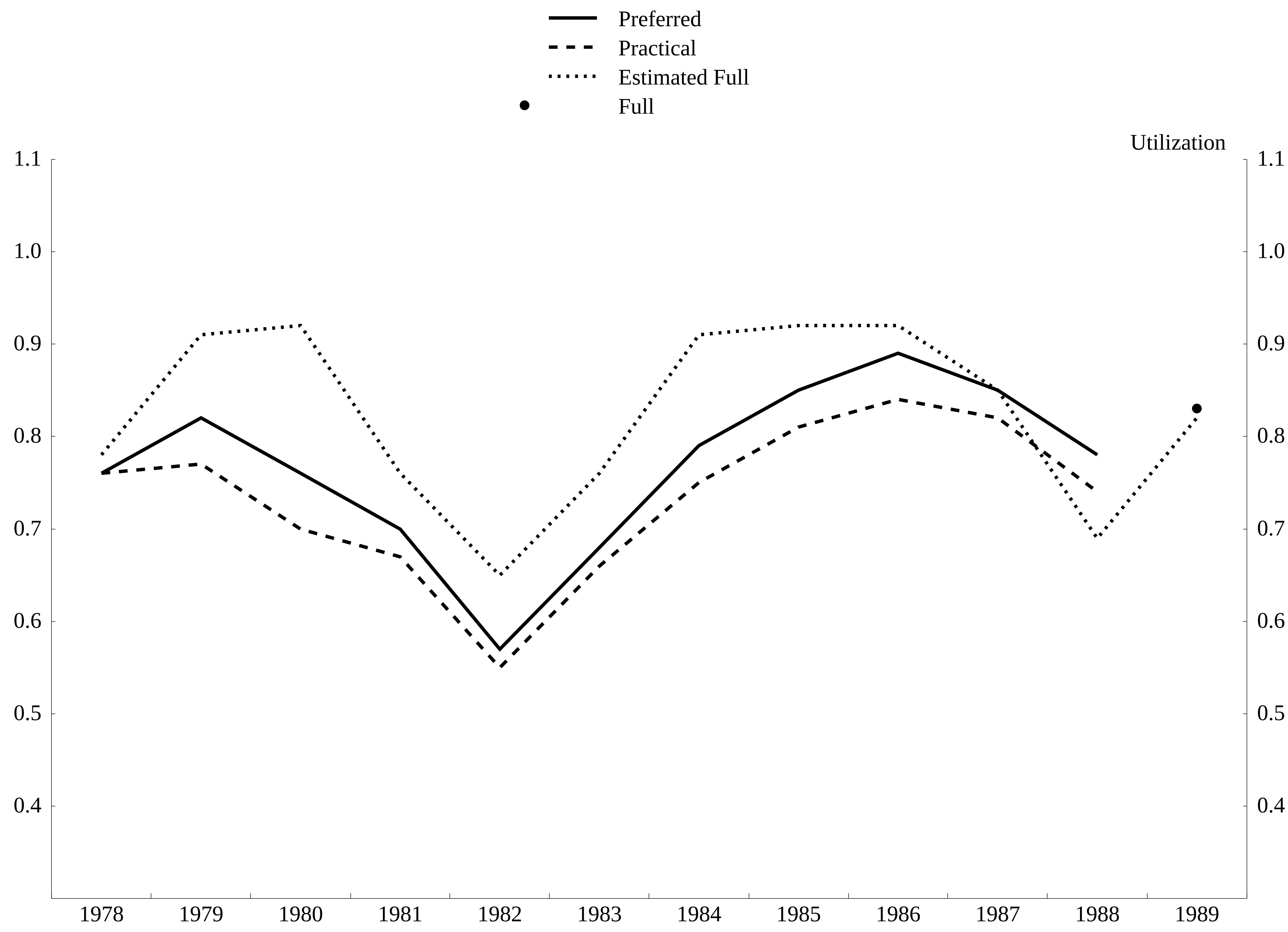


Figure 19: Comparison of Utilization Measures
SIC 33

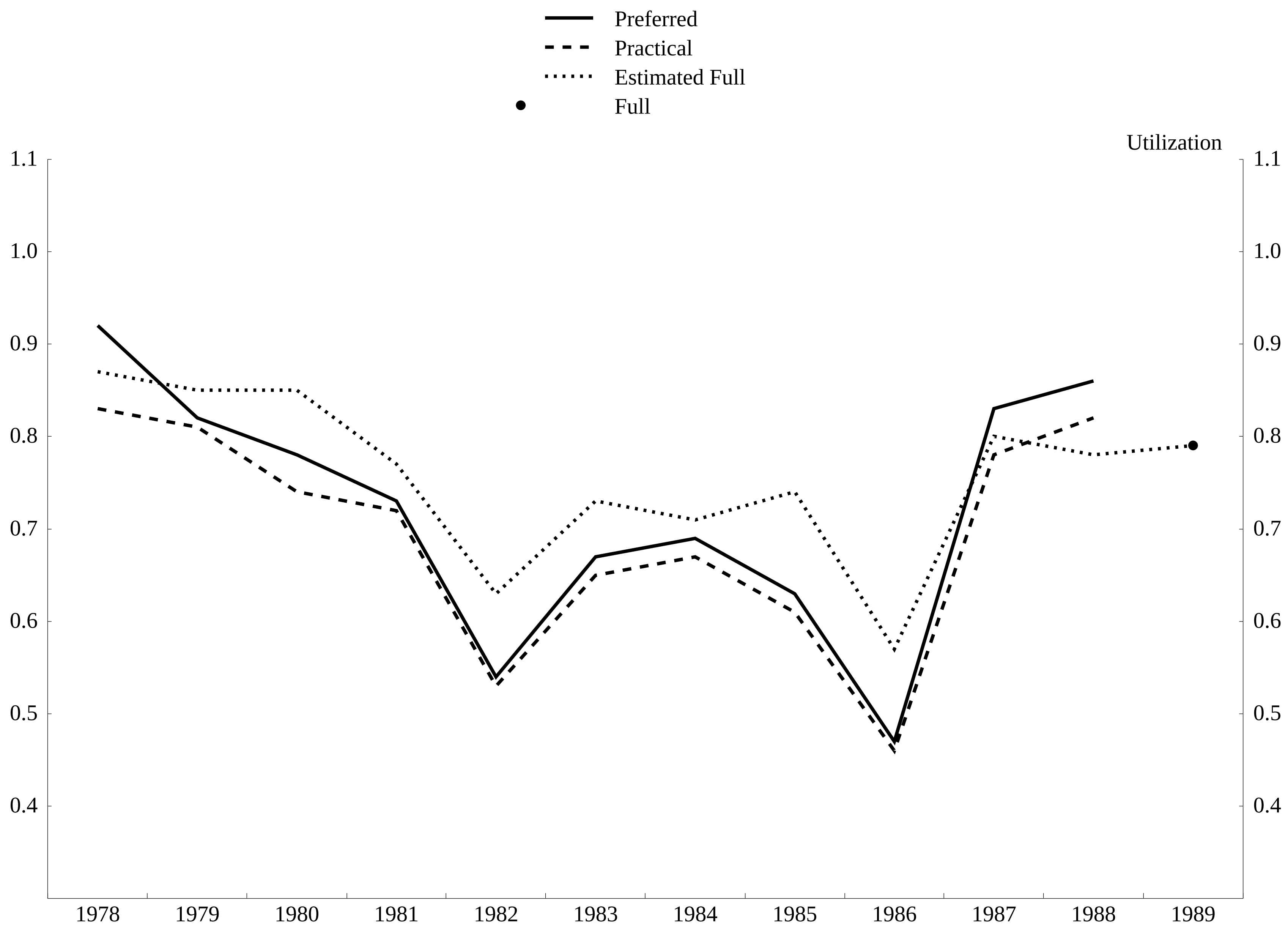


Figure 20: Comparison of Utilization Measures
SIC 34

Figure 21: Comparison of Utilization Measures
SIC 35

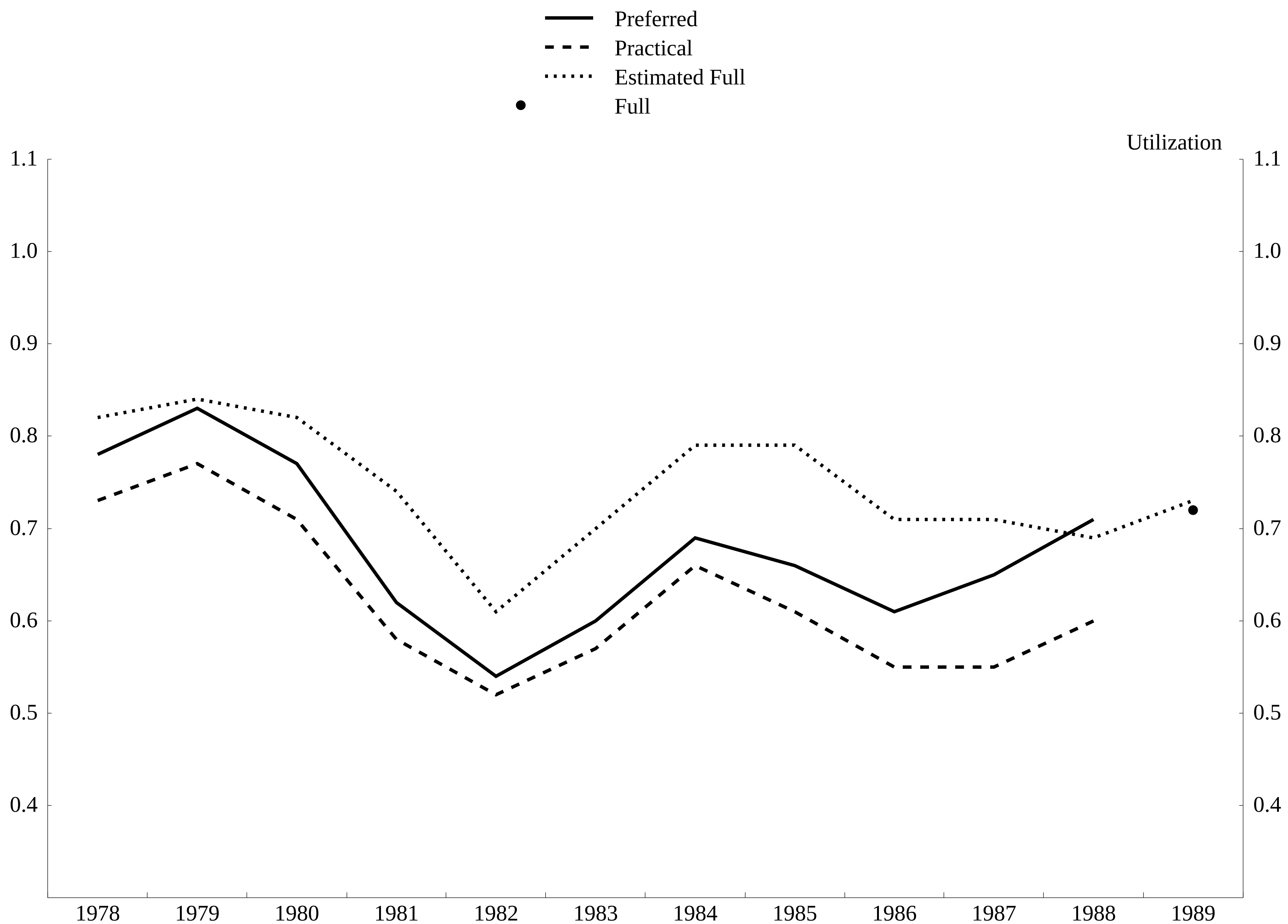


Figure 22: Comparison of Utilization Measures
SIC 36

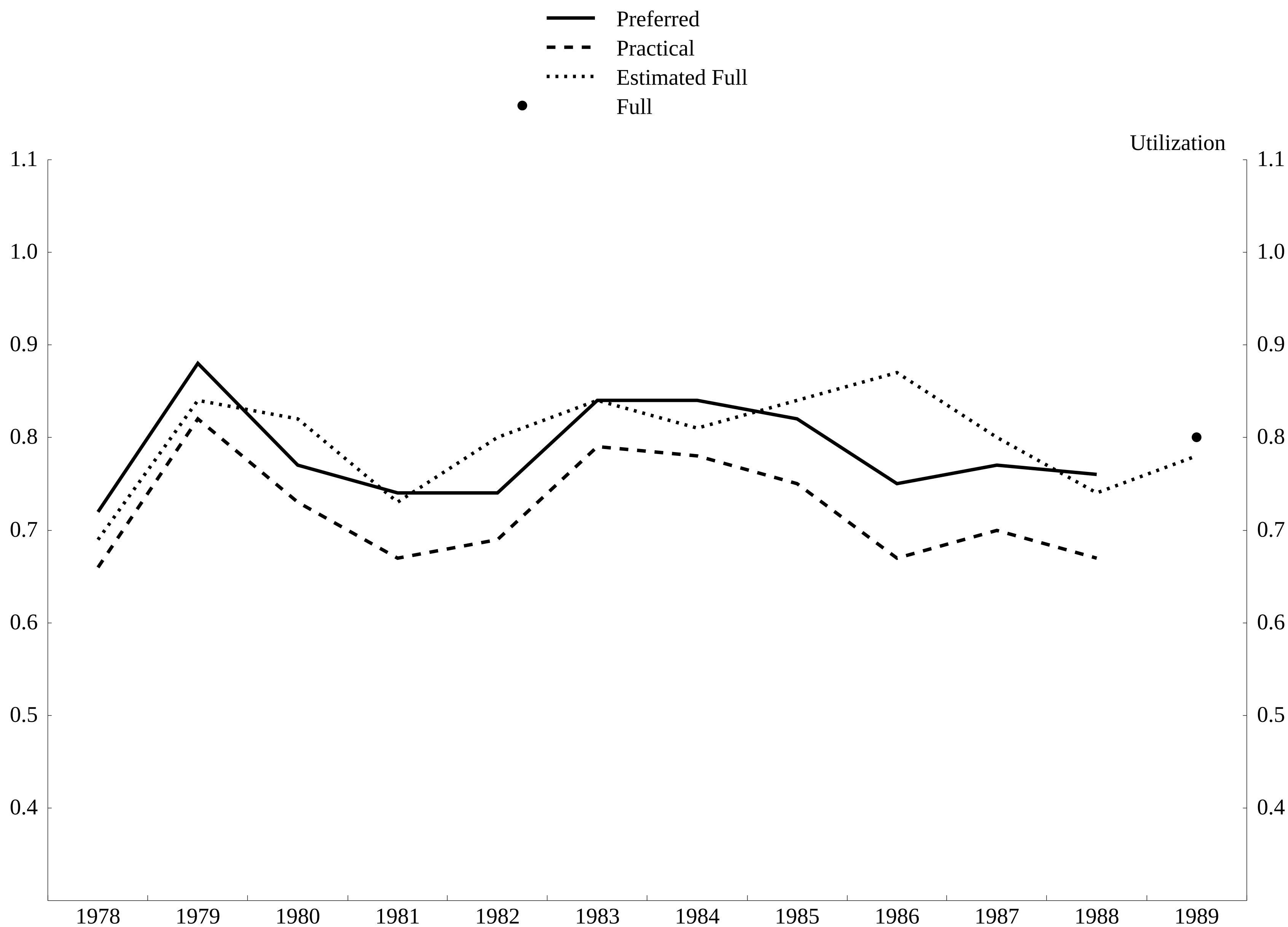


Figure 23: Comparison of Utilization Measures
SIC 37

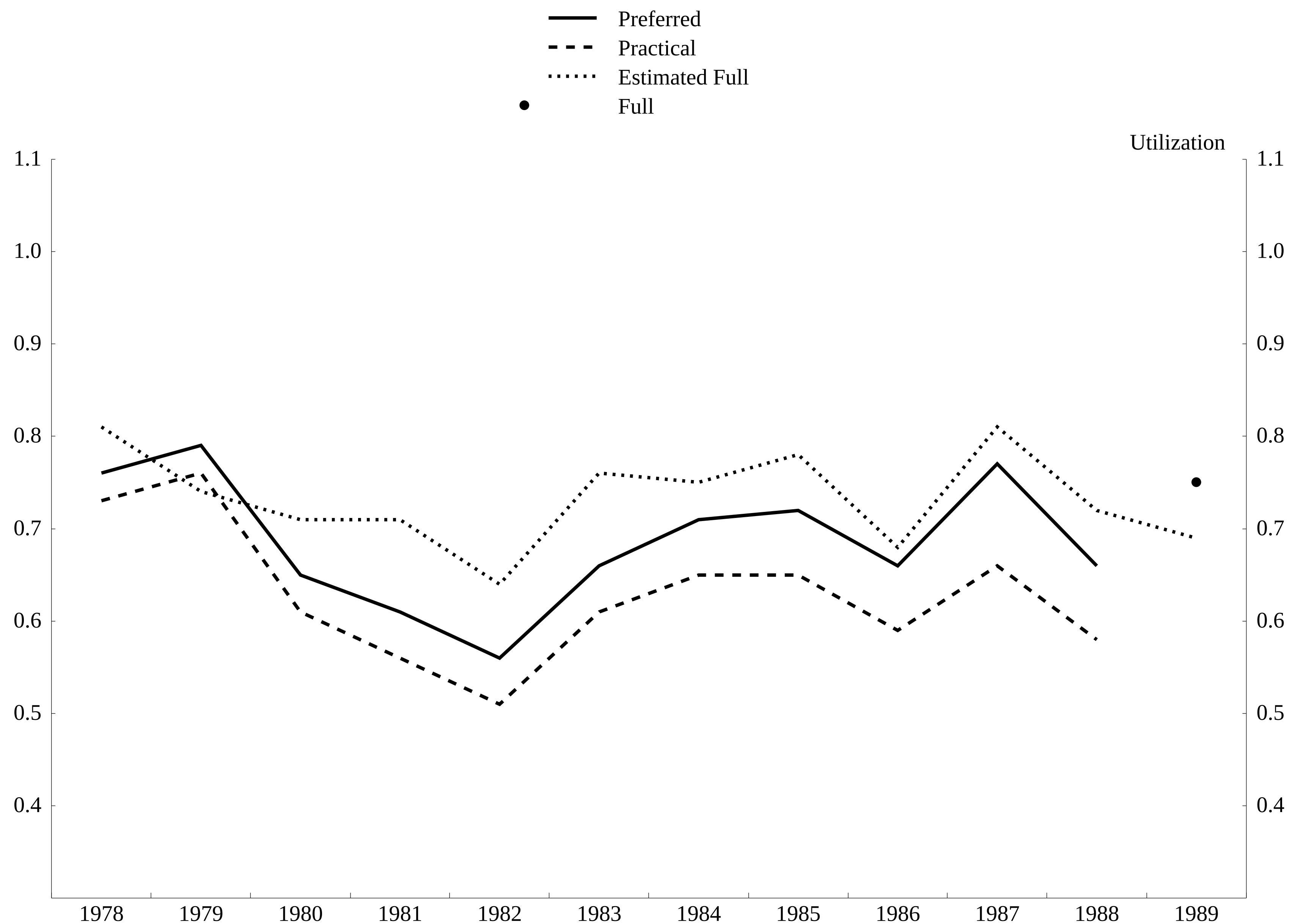


Figure 24: Comparison of Utilization Measures
SIC 38

Figure 25: Comparison of Utilization Measures
SIC 39

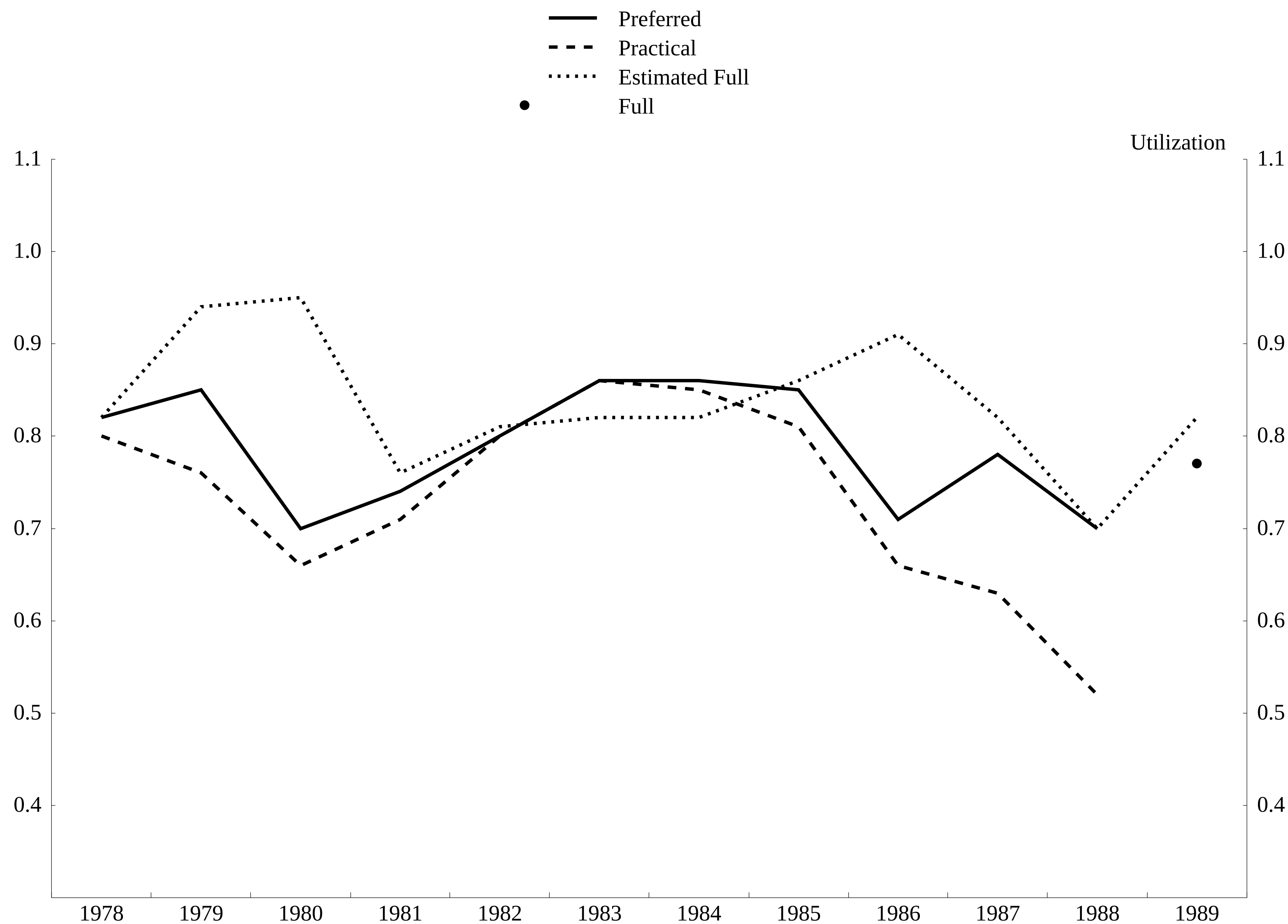


Figure 26: Comparison of Utilization Measures
Manufacturing--Cross Survey Method